AD-A133615

Research Report 1337

AN EVALUATION OF THE EFFECTS OF VARIOUS TASK ASSIGNMENT ALTERNATIVES ON M109A1 HOWITZER CREW PERFORMANCE

Lloyd M. Crumley, Robert C. Schwalm,
and Jay S. Coke

ARI FIELD UNIT AT FORT SILL, OKLAHOMA

U. S. Army
Research Institute for the Behavioral and Social Sciences

July 1982

83 10 17 006

U. S. ARMY RESEARCH INSTITUTE

FOR THE BEHAVIORAL AND SOCIAL SCIENCES

A Field Operating Agency under the Jurisdiction of the

Deputy Chief of Staff for Personnel

L. NEALE COSBY
Colonel, IN
Commander

JOSEPH ZEIDNER
Technical Director

NOTICES

DISTRIBUTION: Primary distribution of this report has been made by ARI. Please address correspondence concerning distribution of reports to: U.S. Army Research Institute for the Behavioral and Social Sciences, ATTN: PERI-TST, 5001 Eisenhower Avenue, Alexandria, Virginia 22333.

FINAL DISPOSITION: This report may be destroyed when it is no longer needed. Please do not return it to the U.S. Army Research Institute for the Behavioral and Social Sciences.

NOTE: The findings in this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Research Report 1337	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) AN EVALUATION OF THE EFFECTS OF VARIOUS TASK ASSIGNMENT ALTERNATIVES ON M109A1 HOWITZER CREW PERFORMANCE		5. TYPE OF REPORT & PERIOD COVERED --
		6. PERFORMING ORG. REPORT NUMBER --
7. AUTHOR(s) Lloyd M. Crumley Robert C. Schwalm Jay S. Coke		8. CONTRACT OR GRANT NUMBER(s) --
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Research Institute for the Behavioral and Social Sciences 5001 Eisenhower Avenue, Alexandria, VA 22333		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 2Q263743A790
11. CONTROLLING OFFICE NAME AND ADDRESS --		12. REPORT DATE July 1982
		13. NUMBER OF PAGES 71
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) --		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE --

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

--

18. SUPPLEMENTARY NOTES

--

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Performance
Crew effectiveness
Crew simulation
Howitzer crews
Field Artillery crews
Computer models
Personnel utilization

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The crews of Army weapon systems must be prepared to operate and support their weapon systems under battle conditions which can have serious debilitating effects on the performance of crew members. It follows, therefore, that when decisions concerning the size and task assignments of crew members are made, the effects of these potentially debilitating parameters should be considered. The cost of studying alternative crew structures to determine the effect of even a single parameter over the course of a battle is almost prohibitive. ARI has developed a crew modeling technique that permits crews of various sizes, with

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. Abstract

different task assignments to be simulated. The crew simulation model also has the capability to modify crew member performance by the application of decrement (or increment) data from tables which represent the impact of selected parameters on human performance. This report describes the use of the crew simulation model to evaluate the effect of different divisions of the ten man howitzer crew between the operating and support tasks. Time to perform estimates were obtained for 10, 9, 8, 7, 6, 5, and 4 persons assigned to emplace, fire, and march-order duties. Support task requirements were determined and man-hour estimates for these tasks were developed to quantify the requirements.

Results suggest that a 5/5 crew split with each half-crew alternating between on-howitzer and support functions (including sleep) has the best chance of meeting the demands for timely artillery fire and high fire rates over periods of extended combat. The report demonstrates that a five man crew can operate the weapon to approximately the same time standards as the full crew while providing nearly adequate support man-hours to meet the requirements of high intensity battles. The analysis also shows how a 5/5 split crew utilization approach has a satisfactory ability to respond when people are lost, better transfer capability from garrison to battle and is more easily and effectively used in a garrison situation than the present single unit crew concept.

Research Report 1337

AN EVALUATION OF THE EFFECTS OF VARIOUS TASK ASSIGNMENT ALTERNATIVES ON M109A1 HOWITZER CREW PERFORMANCE

Lloyd M. Crumley, Robert C. Schwalm,
and Jay S. Coke

Submitted by:
James A. Bynum, Chief
ARI FIELD UNIT AT FORT SILL, OKLAHOMA

Approved by:
Edgar M. Johnson, Director
SYSTEMS RESEARCH LABORATORY

U.S. ARMY RESEARCH INSTITUTE FOR THE BEHAVIORAL AND SOCIAL SCIENCES
5001 Eisenhower Avenue, Alexandria, Virginia 22333

Office, Deputy Chief of Staff for Personnel
Department of the Army

July 1982

Army Project Number
2Q263743A790

Crew Design

ARI Research Reports and Technical Reports are intended for sponsors of R&D tasks and for other research and military agencies. Any findings ready for implementation at the time of publication are presented in the last part of the Brief. Upon completion of a major phase of the task, formal recommendations for official action normally are conveyed to appropriate military agencies by briefing or Disposition Form.

FOREWORD

The Fort Sill Field Unit of the U. S. Army Research Institute for the Behavioral and Social Sciences (ARI) is conducting research on a methodology for evaluating crew performance on crew manned weapon systems. The approach involves a computer based crew simulation model in which crew size, crew member task assignments, and task times can be varied. The Crew Performance Model can then be used to simulate crew performance or to evaluate the effects of changes in equipment. With the addition of appropriate task type based performance decrement tables the model can also be used to predict crew performance in various battle conditions. The model has been developed with data obtained from M109A1 howitzer sections and has been reported in earlier reports.

This report demonstrates how the model can be used to evaluate the effects of crew structure changes. Various methods of using the ten man howitzer crew are examined and various task assignment alternatives compared. The work was accomplished by ARI personnel under Army Project 2Q263743A790, FY 81. Additional reports will be made as the model is validated and data are incorporated to extend the model's applicability.

JOSEPH ZEIDNER
Technical Director

A

This page intentionally left blank.

An Evaluation of the Effects of Various Task Assignment Alternatives on M109A1 Howitzer Crew Performance

BRIEF

Requirement

To develop and demonstrate a method of evaluating the performance of crews on crew served weapon systems without the need to train and test crews under all the conditions in which performance data may be desired.

Procedure

A model has been developed which simulates crew performance. The model enables the analyst to vary crew sizes, tasks and task assignments to test different crew arrangements. The model has been tested using task time data collected from two III Corps M109A1 howitzer crews. The task lists and task times have been entered into the model's task library section. For this study the model was used to simulate different numbers of crew members performing the tasks necessary to emplace, fire and march-order a howitzer section. Crew performance, expressed as time to set-up, fire and/or march-order, was estimated from the model.

A further analysis was made of the support tasks which must be performed in order for the howitzer section to be protected from undue risk and its assets replenished as the battle continues. Estimates of the man-hours which these tasks require were obtained, where possible, and the man-hours available for different crew sizes were compared to the support requirements.

Findings

The model derived data showed that the median time required to emplace, fire or march-order an M109A1 howitzer section increased only slightly as the number of crew members assigned to those duties were decreased from the Technical Manual crew utilization philosophy (which assigns ten men to emplacement tasks, eight men to firing tasks and nine men to march-order tasks) to a crew structure that assigned only five men to those sequences. Emplacement, including boresighting, took 5% longer than the ten man Technical Manual method. Firing a one round mission took 8.6% longer and march-ordering took 14.7% longer. Further analyses of the data showed that the longer firing times can be shortened to below the eight man firing times with minor equipment changes and that much of the 14.7% march-order difference is an artifact due to the Technical Manual assumption that all crew members, except the gun guide, are at the weapon each time a march order begins.

Other analyses also showed that as the number of crew members assigned to emplace/fire/march-order tasks are decreased from 10/8/9 to 5/5/5 the number of man-hours available each day for support tasks increases from approximately 48 man-hours to 120 man-hours. Since support tasks are extensive enough to require more than 120 man-hours/day/section, particularly during high fire rate (400-500 rounds per section) days, using the ten man crew as two five man units (5/5) appears to be the best crew structure alternative.

Utilization of Findings

Results suggest that serious consideration should be given to formally adopting a crew structure strategy that divides the M109A1 howitzer crew into two identical five man units.

AN EVALUATION OF THE EFFECTS OF VARIOUS TASK ASSIGNMENT ALTERNATIVES ON M109A1 HOWITZER CREW PERFORMANCE

CONTENTS

CONTENTS (Continued)

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The Army Research Institute is currently conducting a research program to develop a method and obtain the data required to evaluate the performance of weapon crews operating in full or degraded modes under certain combat conditions. The basic approach involves developing a computer-based model which will meld modifications of selected industrial "methods engineering" techniques with appropriate human performance data in order to predict crew performance without the need to create, train and measure each crew structure alternative in simulated battle conditions.

The basic research approach, depicted in Figure 1, involves creating a computer-based model which will simulate a crew performing all, or selected portions of, the tasks required to operate the system being studied. The model operates with inputs representing tasks and task times and, when completed, will contain tables defining the performance decrements which occur as crew members are subjected to battle conditions which impair their effectiveness.

Two portions of the project have been completed to date. A crew simulation model has been developed (see Schwalm, Crumley, Coke, & Sa s, 1981) and a task and task time library has been created for the M109A1 howitzer (see Coke, Crumley, & Schwalm, 1981). At present crew size and task assignments for an M109A1 crew can be varied in the Crew Performance Model in order to determine what effects such changes may have on the crew's first day of battle performance times. Using the model an analyst can change crew structure by merely making computer entries and can quantify the effects of such changes by playing the model for a selected number of iterations.

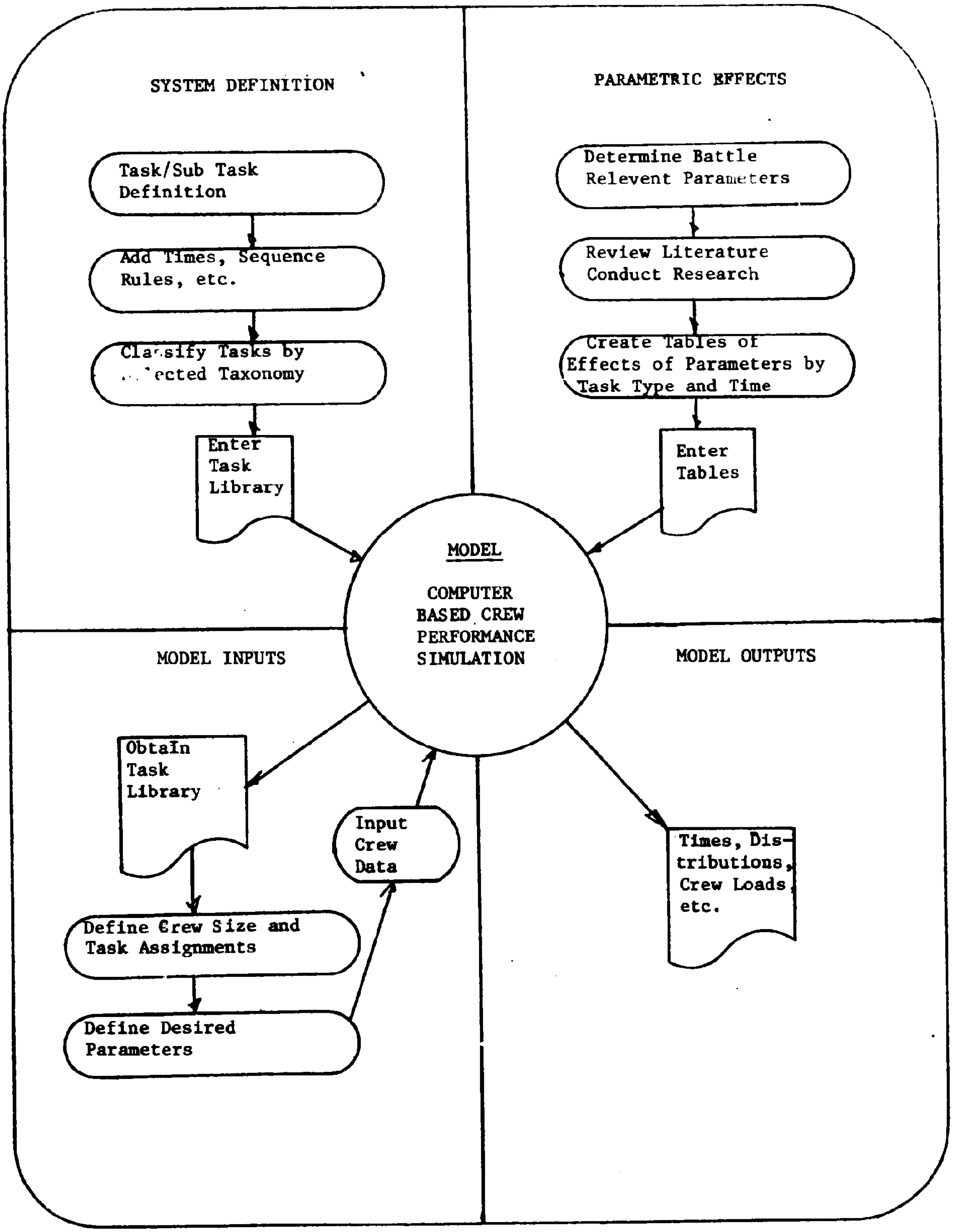


Figure 1. Diagram of basic approach to developing a methodology and data to determine the effect of crew structure on performance in sustained combat.

In approaching the simulation problem we have analyzed the nature of the tasks which must be performed to operate a howitzer section in combat. Such tasks fall into two basic groups. One group includes tasks which are amenable to various kinds of structuring with regard to who performs them and/or in what order they are performed. These tasks, called discrete tasks in the report, also lend themselves to analyses which consider time to perform, by the crew, as a measure of effectiveness of crew performance. The other class of tasks is of a type that does not lend themselves to modification to improve performance time. These tasks--often called "level-of-effort"--simply take whatever time is allocated to perform them and whether they are done or not is essentially a function of the time available to attend to them.

The modeling approach described in this report focuses on the discrete tasks in order to determine what effects various numbers of assigned persons have on time to perform. This in turn allows a determination of the number of man-hours available each day for scheduling the level-of-effort tasks.

Howitzer crew activity as it is defined in the current Technical Manual was evaluated and base case data developed. Some additional crew assignment arrangements were modeled and compared with the base case crew performance. One particularly effective approach was identified and a fairly extensive comparison between it and the base case approach is reported. We then used crew data and support requirements data to show that even with a more effective crew structure more man-hours per day are needed to complete support tasks than are available from a

ten person crew. The use of an 11 person crew structure to alleviate this problem is discussed.

PURPOSE

The purpose of this report is two-fold: to develop a rationale for future crew performance evaluations and to report some preliminary crew structure results. The body of this report discusses the crew assignment problem and describes the implications of results obtained by using the model to evaluate differing crew structures. Later reports will extend the use of the simulation to other system types and will demonstrate the use of the model to evaluate factors that influence performance.

APPROACH

Any approach to the problem of modeling crew performance in extended operations requires that a rationale be developed so that the model and its results are accepted as representing crew performance. This "rationale development" involves two separate areas, both of which must be handled adequately in order for the model's results to be accepted. One area is the definition of what will be modeled. The other area is a description of the logical mechanisms that lead to the computer program which is the basis for the simulation. Therefore, the simulation must model meaningful activity and must manipulate this material in a fashion that is seen as realistic. Stated another way one can ask: "How has the problem been defined?" and "What has been proposed as the solution?"

THE PROBLEM

An M109A1 howitzer section as described in Technical Manual (TM) 9-2350-217-10N consists of a crew of ten, a howitzer and a section vehicle.

In future battles it is postulated that crews will be required to operate around the clock for periods of some eight to ten days. During this period they will move as often as six to twelve times a day and fire at rates varying from 125 to 500 rounds per 24 hour period. Figure 2 shows a fire rate by day of battle estimate which has been used in past Field Artillery School presentations to represent the nature of the anticipated fire rates for a first battle in Europe scenario. The firing rates are graphed in six hour increments. The same data are shown in Figure 3 where a cumulative count of rounds fired is shown plotted against time of battle.

Figure 3 also shows a series of hypothetical moves by the howitzer section. In estimating the number of moves it was assumed that a section would move once for every 50 rounds fired. Sometimes the move would be the result of repositioning required because of changes in location of the Forward Edge of Battle Area (FEBA) and in other cases the moves would be relocations to avoid counterfire. Battery moves would not be as regularly spaced as shown in Figure 3 and, indeed, the number of rounds fired and number of moves might vary somewhat from the number shown. Despite this, the data in Figures 2 and 3 illustrate the great demands which can be brought on a section crew in actual combat. In the projected scenario, with an assumption of one move every 50 shells fired, the section fires 2060 rounds and moves 41 times during the battle. Can a ten man howitzer crew do this? If so, how should the crew workload be assigned in order to best accomplish it? These are the questions that the research program seeks to answer.

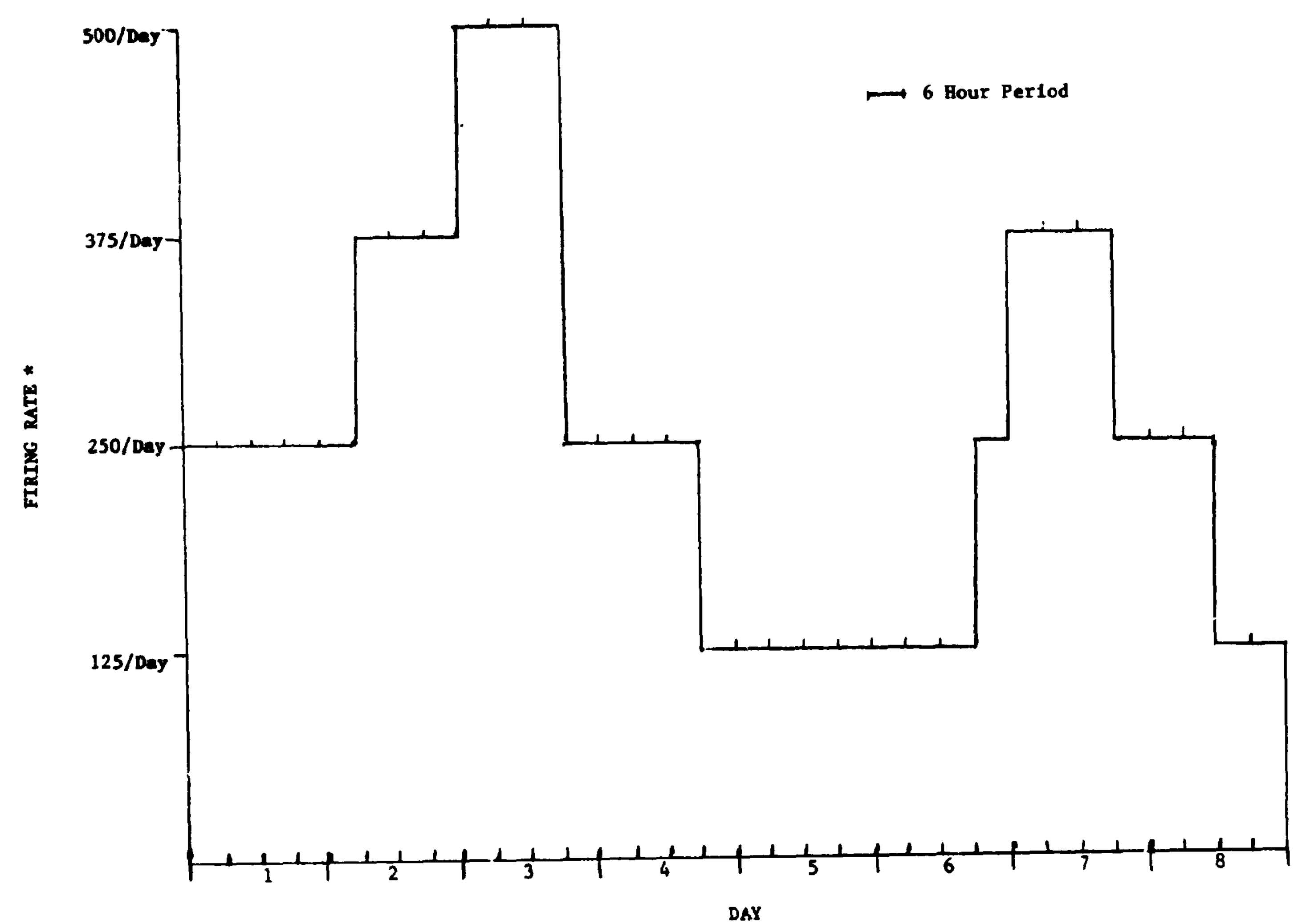


Figure 2. Fire rate by six hour period for a potential first battle in Europe scenario.

*In rounds per howitzer per day.

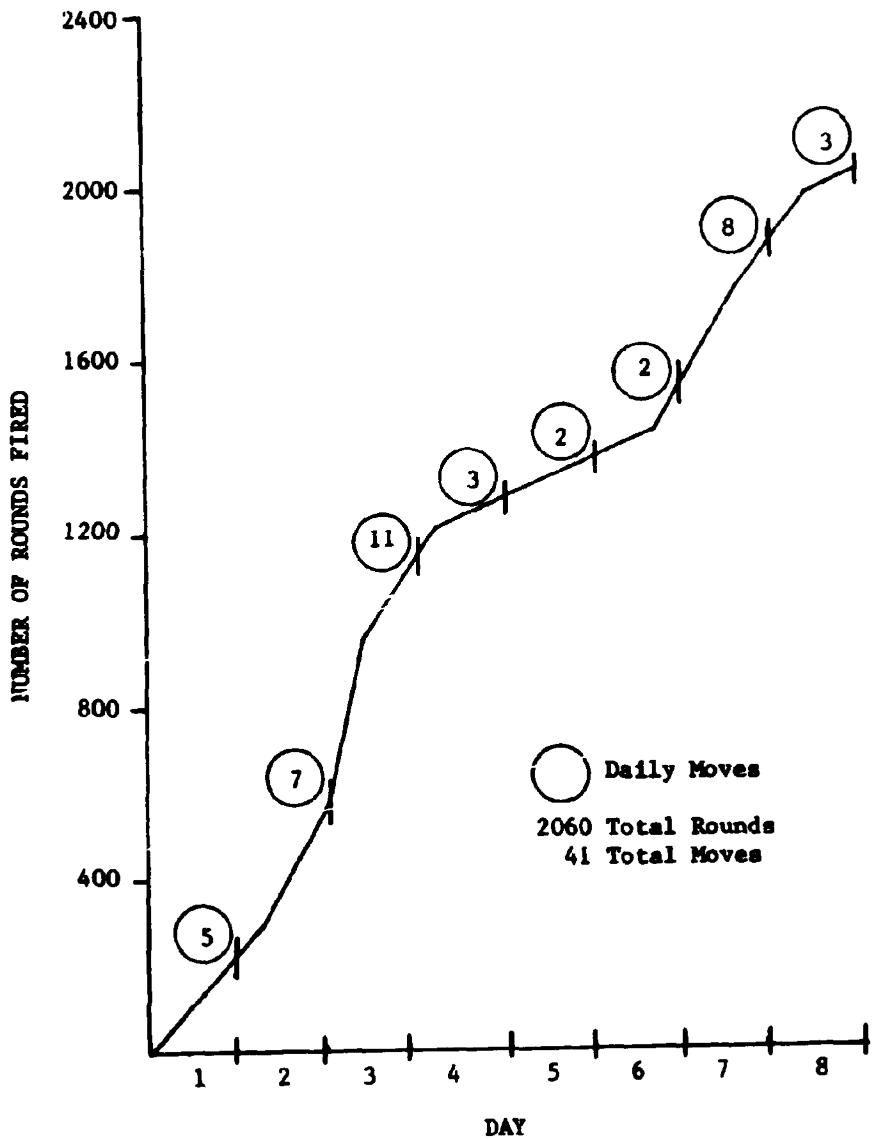


Figure 3. Cumulative rounds fired by battle day and number of moves each day based on a one move per 50 rounds fired estimate.

TASK TYPES

In order to model crew structures and analyze a crew's ability to withstand the demands of an extended, continuous battle it was necessary to address the various tasks which a howitzer crew must perform. The rationale that was developed classified the tasks and considered the class types in a specific order. Three parameters were considered: the type of task, the purpose of the task and the impact of the task on the section's resources. The classification scheme is shown in Table 1 and is based on the task characteristics described in the following sections.

Table 1

Dimensions of Task Activities

Type	Discrete <u>vs</u> Level of Effort (LOE)
Purpose.	Fighting <u>vs</u> Support
Impact . . .	Resource Expending <u>vs</u> Replenishing or Risk Reduction

<u>Discrete vs Level-of-Effort (LOE)</u>

A <u>discrete task</u> is one that has a start and stop point, is limited by the task itself in terms of the number of persons who can work on it, and is part of a sequence that, if it is performed faster, can be completed earlier with a consequent freeing up of personnel to go on to other duties or to repeat the task. Examples are tasks such as "selecting a fuze and putting it on the projectile". Such tasks are variable in the time it takes to perform them and when the task is over the crew member is free to go on to another task. If discrete tasks are performed slowly, or if some tasks in a task sequence hold up performance of other tasks because of poor task sequence arrangement, the affected crew members are not free to go on to other task sequences. Discrete

tasks are such that they can be performed more rapidly with effective training and lend themselves to rearrangement to improve the crew effectiveness. Discrete tasks generally are also short tasks, requiring seconds, or at most minutes, to complete.

The term level-of-effort (LOE) is applied to cover tasks which are not considered as discrete. This category includes such items as standing guard, preparing defensive positions and sleeping. Some tasks which we have considered as LOE are mixed and have discrete type tasks embedded in them. Replenishing ammunition is such a task. The actual off-loading of ammunition from the truck to the section vehicle consists of a series of movements that could be treated as discrete, but these tasks are also part of a longer term process of going for, obtaining, returning and transferring ammunition. This being the case, this task, and others of the same character, can be considered as LOE since the LOE portion so overshadows the discrete portion.

The reason for the discrete vs level-of-effort task distinction is to simplify the model. The model is intended to evaluate the effect of continuous operations on crew performance. The tasks we have classified as discrete lend themselves to analysis by the modeling approach we have adopted. They can be assigned in different orders and to different crew members; they can be evaluated individually to determine the effects of various parameters, such as training or fatigue; and, fortunately, they are all involved in crew processes in which the quicker they are properly performed the better the crew performs.

LOE tasks, on the other hand, have few of the attributes which characterize discrete tasks. LOE tasks tend to be a scheduling problem

rather than a crew structure problem. The LOE tasks take longer to perform, do not lend themselves to a "quicker is better, so we should train to perform them faster" approach and usually have little or no room for being speeded up by a more efficient method. They may be done well or poorly but it is quality of performance and not time that varies.

Fighting vs Support

In developing a rationale for the ARI model we have also considered the purpose of tasks. The various tasks performed by howitzer crew members may be considered as being in one of two categories which describe different purposes.

Fighting Tasks. Fighting tasks include all those tasks which must be performed when a howitzer section is emplaced, fired, march-ordered or driven to a new location.

Support Tasks. These tasks are all the tasks not classified as fighting tasks. They are performed in order to maintain the ability of the section to continue to perform its fighting tasks.

Resource Expending vs Replenishment and Risk Reduction

Finally, tasks may be considered in terms of their impact on the section's resources. The fighting tasks all expend resources, e.g., firing uses ammunition, moving uses fuel and men get tired. Support tasks on the other hand are intended to restore or conserve resources and, hence, they either:

(1) replenish resources expended as the section moves and fires, or

(2) reduce the risk that the section will be placed in a position where its resources will be unnecessarily expended.

The task categories provide a basis for considering the total task load on a howitzer crew in a series of steps rather than in a single

stage. Thus, in modeling the crew, and in actual operations, the process of deciding if a crew can perform adequately is best answered by determining first if they fight the howitzer adequately and second if they have time to schedule the necessary support tasks.

MEASURING CREW EFFECTIVENESS

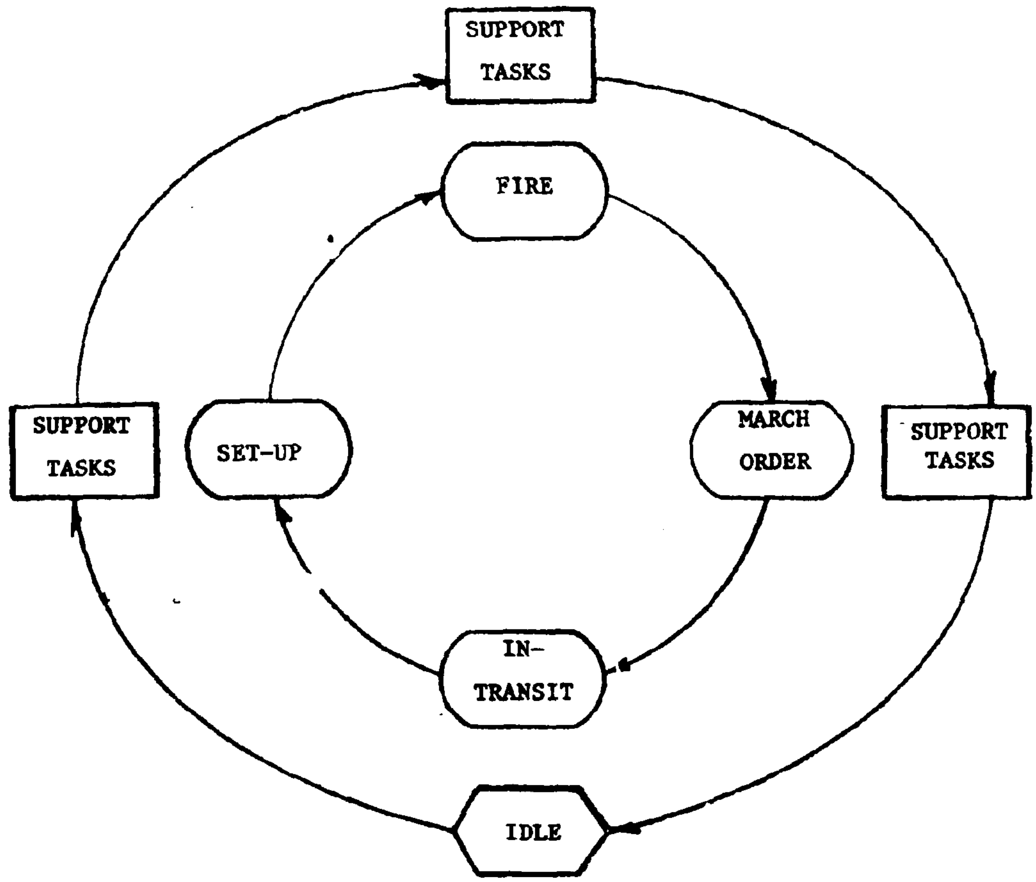
Because the primary role of the howitzer section is fighting, a crew structure must enable the fighting tasks to be accomplished throughout the course of the battle. Thus, the ability of the crew assigned to the fighting tasks to perform its required duties is actually one measure of whether or not a crew structure is adequate. Therefore the crew personnel assigned to the fighting tasks must meet these goals:

Goal 1. Be able to emplace, fire, march-order and transfer the section in an acceptable time or at an acceptable rate.

Goal 2. Permit enough people to be assigned to the support functions so that lack of support does not reduce the section's fighting ability to an inadequate level.

Goal 3. Have a reasonable capability to continue to respond, in a degraded mode, when section personnel are lost.

As shown in Figure 4 three of the four major task sequences involved in fighting a howitzer are composed entirely of discrete tasks. The fourth sequence, the in-transit phase, is composed of only LOE tasks. It is feasible, therefore, to model the set-up, firing and march-order sequences and evaluate how well various crew sizes and crew structures meet time standards for performing these phases. This approach makes speed of performance a measure of a crew's ability to perform the task sequences involved in fighting the section, except for



- Set-up, fire and march order tasks are -
  (1) discrete
  (2) expend resources

- In-transit tasks are -
  (1) level of effort (LOE)
  (2) expend resources

- Support tasks are level-of-effort and either replenish resources or reduce risk.

Figure 4. Phases of fighting and supporting a howitzer section.

the in-transit period. The in-transit period involves the entire crew with some of them working at LOE tasks and the remainder either involuntarily idle or able to perform only minimal personal support duties.

The allocation of available man-hours to the support functions then becomes a scheduling problem. The number of persons not assigned to fighting duties determines the amount of time available for the support functions. Judgments must be made concerning the priority of the various replenishment and risk reduction tasks in order to assign the available personnel effectively. The effectiveness of a crew structure in meeting the support task requirements is therefore measured by matching the man-hour requirements needed to perform the support tasks with the man-hours the crew structure provides to attend to them. The crew structure analyst must ask, "How many persons can be removed from the fighting tasks before they are inadequately performed?" and "Is this enough persons to provide adequate support?"

A crew structure that meets the discrete task time standards and provides enough man-hours for the required support tasks is fully adequate. Structures that do not fully meet both these requirements become increasingly inadequate as a function of both the lack of adequate support man-hours and the additional time required to perform the fighting tasks. Selection between sub-optimal alternatives for actual operations is a problem that requires the kind of data that the Crew Performance Model can provide but ultimately it is a problem that is solved by the use of judgments, constraints and data that go beyond crew performance modeling.

TIME AVAILABLE AND TIME REQUIRED FOR SUPPORT TASKS

The present standard crew operating procedure is defined in TM 9-2350-217-10N. The TM crew operating procedure indicates that ten men emplace a howitzer section, eight fire it, nine march-order it (the Gun Guide usually having gone ahead) and, of course, either nine or ten men are in-transit as the section moves between locations.

It appears that this crew utilization philosophy cannot sustain the section in an extended, continuous high intensity battle situation. There are two reasons for this conclusion. The first reason is that a section crew has a significant number of <u>support</u> functions which it must accomplish in order to maintain its ability to fight. The second reason is that since the howitzer must be available to fire at all times (when not moving) the support duties must be done concurrently with the firing of the weapon. This latter constraint imposes the requirement that some sort of an alternation of crew members between fighting and support tasks must exist so that crew members are off the weapon at least for the minimal time needed to perform their personal support functions--most notably sleeping.

Technical Manual Fighting Task Sequences

The M109A1 crew structure defined in the Technical Manual creates a situation where little manpower is available for assignment to support duties. When the gun is emplaced and available for firing, two persons are available for support duties; but during emplacement no one is available, and only the gun guide support function is filled during march-order. Thus, if a section were to remain in one location for an entire day, 48 man-hours would be available for support duties. Since

four hours sleep per man each day is a minimal support function for a man, 40 (10 men X 4 hours) of these 48 hours would be required just to provide the crew with minimum rest.

Table 2 shows the man-hours per day that would be available for support duties for two possible operating conditions and with crews of varying size. The "No Moves" column is based on the case where no time is required to march-order, transit and set-up because no moves are made. The "Four Hours Moving" column assumes a move situation that permits the section to be reported up-and-ready only 20 hours per day. This latter case is an approximation of the 21 hours per day that guns were in position ready-to-fire in a 96 hour field evaluation of a simulated battle with an average of four moves per day required (Crumley & Schwalm, 1980).

Table 2

Time Available for Support Duties Assuming Different Firing Duty Assignments and Two In-Position-Ready-To-Fire Times

Firing Crew Size	Support Man-Hours/ Day with No Moves	Support Man-Hours/Day with Four Hours Moving
8	48	40
7	72	60
6	96	80
5	120	100
4	144	120

It would be possible to arrange a system in which a section did not have to be split. This would require that the entire section crew

alternate between the firing and the support duties. This has never been seriously considered as a solution since it has the effect of reducing the number of weapons available to fire in direct proportion to the requirements for support duties. This makes the solution non-viable since it can easily be shown that support requirements rise as firing rates increase, and, hence, some guns would either be "down but supported" or "up but not supported" at the most critical periods of battle. This being the case the gun must always have a portion of the total crew available to fight it while the remainder of the crew is supporting it if it is to be available at all times.

Support Tasks

It was noted earlier that support tasks could be classified as either replenishment or risk reducing tasks. Table 3 shows a list of support tasks. There may be others but even with this list it can be shown that the support duties form a considerable block of howitzer duties. The times shown in Table 3 were obtained from various sources. Generally the data were from doctrine requirements or from available estimates taken from Field Artillery School documents. Table 3 shows an estimated 129 man-hours per day which must be spent on support tasks and there are additional tasks which have not been assigned estimated performance times.

The time estimates shown in Table 3 are based on requirements determined after assuming the battery was operating as an eight gun unit and that move requirements would place the section in-transit for four hours in the 24-hour period. Thus, there is a four hour period when for all practical purposes only the vehicle drivers, the air guards and the

Table 3

List of Support Tasks, Classified as Replenishment or Risk Reducing, and Selected Estimates of Time Required to Perform Them while Moving Four Hours Per Day

	Replenishment Tasks	Time Estimate in Man/Hours/Day
a.	Replenish ammunition (500 rds)	16.0
b.	Replenish POL	1.0
c.	Non-scheduled maintenance	4.0
d.	Sleep	40.0
e.	Supply SGT duty	6.0
f.	Personal maintenance (eat, hygiene, body functions, weapons and gear)	4.0
g.	Identify and prepare new firing positions	12.0
	(Sub Total Replenishment Tasks)	83.0
	Risk Reduction Tasks	
a.	Preventative maintenance	1.0
b.	Perimeter defense/early warning	20.0*
c.	Guard nuclear ammunition	5.0**
d.	Prepare supplementary positions	***
e.	Prepare latrines, sleep areas, etc.	***
f.	Improve positions	***
g.	Camouflage	***
h.	Screens	***
i.	Foxholes	***
j.	Crew served weapon positions	***
	(Sub Total Risk Reduction Tasks)	26.0
	Involuntary Downtime while Moving	20.0
	Total of Estimates	129.0

*Assumes two guards at each of four stations with battery operating as an 8 gun unit. If it were operating as two, four-gun units this figure would be 40.0.

**Would be 10.0 if battery were operating as two, four-gun units and both had nuclear ammunition.

***Time estimates were not available.

person in charge of the section are performing duties. Other crew personnel are either idle or limited to a narrow range of personal support activities such as eating, resting, etc.

Table 3 shows that the hours required for support functions can exceed 134 hours per day. It is likely that the support tasks which must be performed if a howitzer section is operated around the clock and according to doctrine exceed the ability of the crew to perform them. The Section Chief's problem then becomes making a series of trade-offs. First he must decide how many people he can remove from the firing task assignments; then he must evaluate his immediate situation and set priorities on the replenishment and risk reduction duties required to support his section and the battery. After he has made these decisions he can schedule the available support manpower to perform the most essential support tasks.

RESULTS AND DISCUSSION

The Crew Performance Model was developed using data from two III Corps M109A1 crews. The nature of our model is such that these base data can be used to determine how these two crews, or other equally proficient (or equally unproficient) crews, would operate if different crew structures, with other task assignments, were used.[1] Thus, it is possible to vary the size of crews and the assignment of tasks to the simulated crew members without having to train and observe new crews.

In its present form the model's output can be used to evaluate different crew structures but the model's time values are not necessarily

---

[1] Some FA personnel have suggested that the crews who were measured were unusually slow. Other FA personnel have felt they were "typical" crews but not crews prepared to meet ARTEP standards.

those of "typical" crews or of crews capable of meeting Army Training Evaluation Program (ARTEP) standards. Hence, in the body of this report we deal with relative times rather than absolute times. To do this we have converted the time values to a percentage scale where the 100% value is the median completion time our model determined for simulated crews as proficient as our observed crews performing their roles according to the structure defined in the current Technical Manual.

Our comparisons then are between these base values and the median values for the "same" simulated crews performing the tasks in some other structure. Thus, when our model shows that a particular crew structure takes 5% longer than the base case the reader must realize that while this difference might be 25 seconds for a "slow" crew (such as the ones observed to obtain the base rate data) it would only be 12.5 seconds for a crew that worked twice as fast as our observed crews.

Because the data we report from our model are relative, rather than absolute, the model is limited to crew structure comparisons. The model does not provide the kind of time data that would permit its use to determine crew performance standards. Nor does the model permit a user to multiply some average performance time by the number of times the activity is required each day in order to obtain the time devoted to that activity in a particular scenario.

With regard to these limitations two points should be noted. One, additional data from "ARTEP ready" crews will be collected so the model will reflect better task performance. Second, if in fact the base case data are from slower crews better crews will perform faster. Therefore,

if a user were to use model data to determine total daily time devoted to an activity his results would not necessarily be wrong; they would only be conservative. In any event the model outputs presented here do not require that the base case data be from typical, or best case, crews. These results, as expressed, would not be influenced by faster or slower base data since only relative time values are needed to make the comparisons we discuss in the following sections. Therefore the following discussion and the data on which the discussion is based will enable the reader to understand the time impact of various crew structure decisions without having to train and observe different types of crew arrangements.

COMPARISON OF CREW FIGHTING TASK ASSIGNMENT ALTERNATIVES

The Crew Performance Model deals with the set-up, fire and march-order portions of the fighting cycle (Figure 4). The model simulates performance of those sequences which are composed of discrete tasks. LOE tasks are handled separately by a scheduling process as support tasks are given a priority and are assigned.

The ability to meet the "move and shoot" requirements of a battle is the criterion by which a howitzer section's capability must be judged. Therefore, in deciding the best task assignment structure, the crew's ability to sustain these portions of the section's duties is the most important. Of the four sub-divisions of the fighting sequence only three lend themselves to modifications which trade off the crew's total performance time against the crew's average idle time. The in-transit situation is simply an LOE sequence involving drivers, air guards and one person in charge; the other crew members are compelled to be non-

productive because of their status as passengers in the howitzer and section vehicle. During the other three phases of the fighting sequence improving the efficiency of individual crew members by the judicious restructuring of task assignments can compensate for all or most of the potential delay which results from removing people from the fighting portion of the crew.

The Crew Performance Model was run to determine the effect of various crew task assignments on the performance of howitzer sections. Data obtained from various model runs are shown in Figures 5, 6, and 7. Each model run consisted of 200 iterations. The figures show completion time data for units of different sizes assigned to the fighting tasks and the percentages of time crew members were idle during each activity. In these figures time is expressed as a percentage of the median time the model calculated for a crew performing the task sequence according to the Technical Manual. The vertical lines indicate the time spreads from the 10th percentile (bottom) to the 90th percentile (top) time. The small horizontal lines show the median values.

Firing

In analyzing the time required to prepare and fire a round the model has been played to simulate one-round missions. Thus, in each case the total time includes all the tasks required to obtain the projectile, powder and fuse from within the section vehicle. If multiple round missions were simulated some or all of these preparation tasks would be performed on the second and subsequent rounds, while the other crew members would be loading and firing the first or previous rounds. Thus, the second and subsequent rounds would be fired more rapidly than

the first round. The model can be programmed to simulate multiple round missions, and the time advantage for various crew sizes can be specifically determined.

Figure 5 shows the effects of reducing the number of persons firing the howitzer. It can be seen that as the number of persons assigned to the firing tasks was reduced from eight to four, the relative time required to prepare and fire a round increased. The efficiency of individual crew members also increased, however, as fewer persons were assigned to the tasks. Figure 5 shows that a reduction from eight to only five persons adds a first round firing time penalty of only 8.6% per mission but provides five persons to perform support duties. Thus, up to 120 (5 X 24) man-hours per day are available for support functions. Loss of a fighting unit crew member would reduce the available fighting crew to four persons and the time required to fire a single round mission would increase by 12.7% of the base rate.

It is also clear from Figure 5 that essentially no time penalty accrues as the firing process is restructured from 8 to 7 to 6 persons. Decreased idle time for remaining crew members can, in these cases, compensate for the reassigned members. When the number of persons assigned is reduced to 5, or fewer, a more substantial increase in time to prepare and fire a round results primarily because the projectile preparation and powder charge preparation become sequential rather than parallel events and a delay occurs.

Emplacing

Figure 6 shows the effects of changing crew member assignments during the emplacement, including boresighting, of a howitzer section.

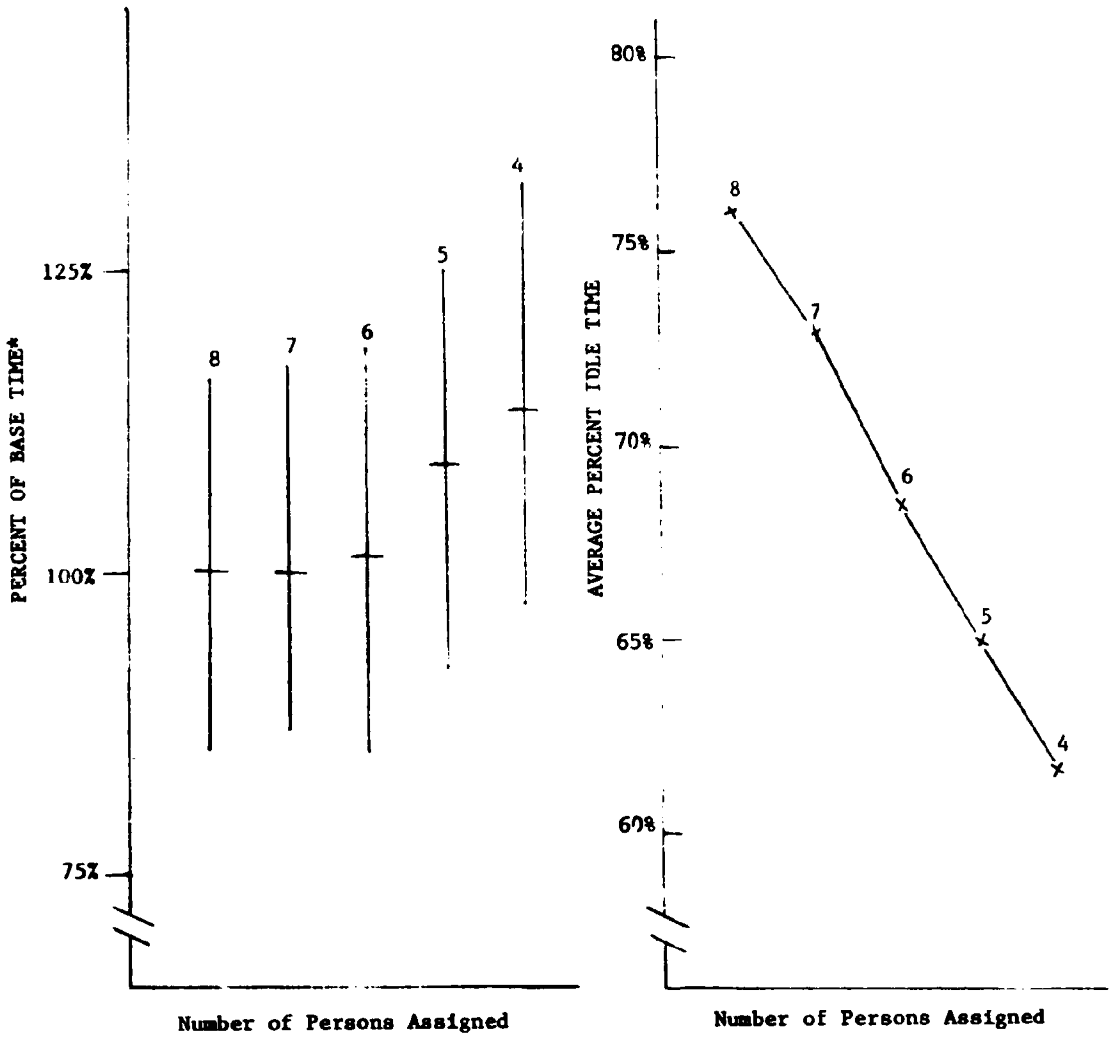


Figure 5. Relative time required to fire a one round mission and crew member idle time for various numbers of assigned persons.

*Expressed as a percent with the median time for an eight man group as 100%.

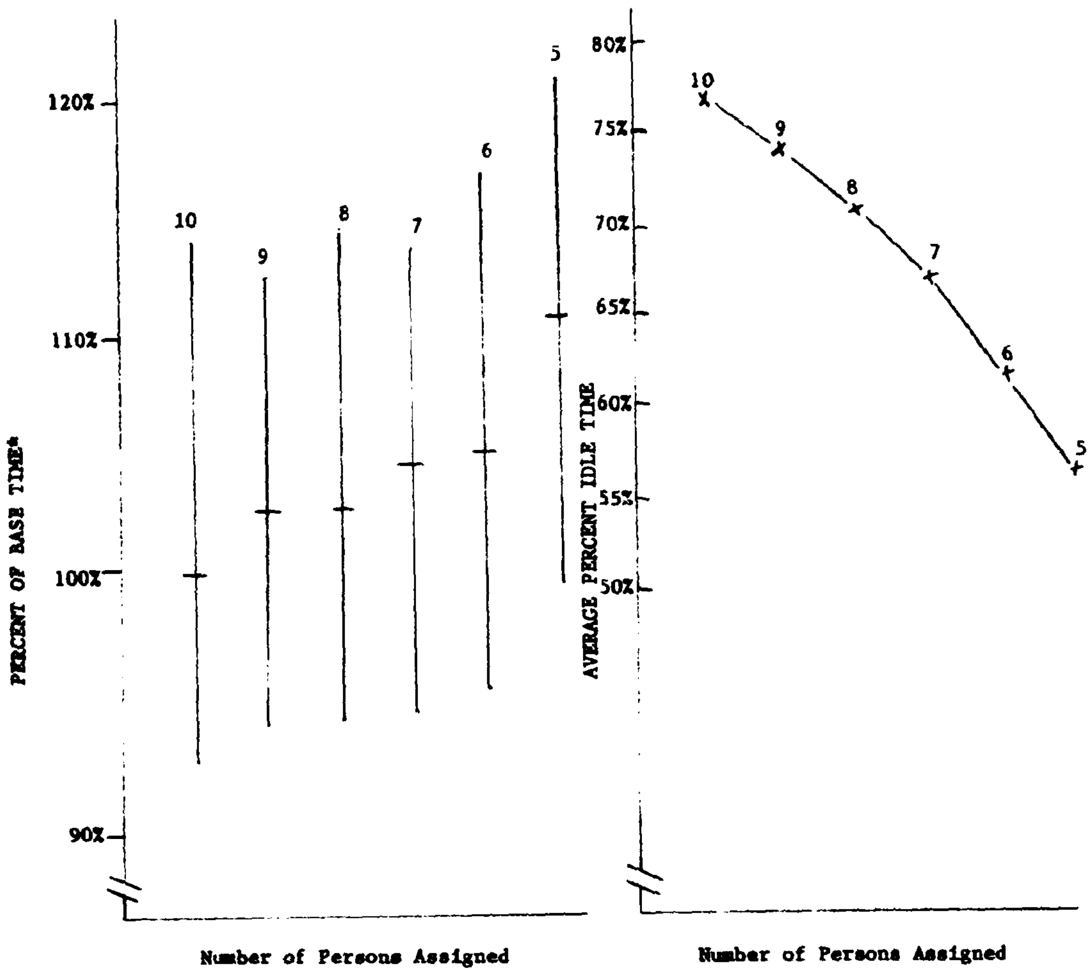


Figure 6. Time required to emplace and boresight an M109A1 howitzer section and crew member idle time for various numbers of assigned persons.

*Expressed as a percent of the median time for a ten-man group.

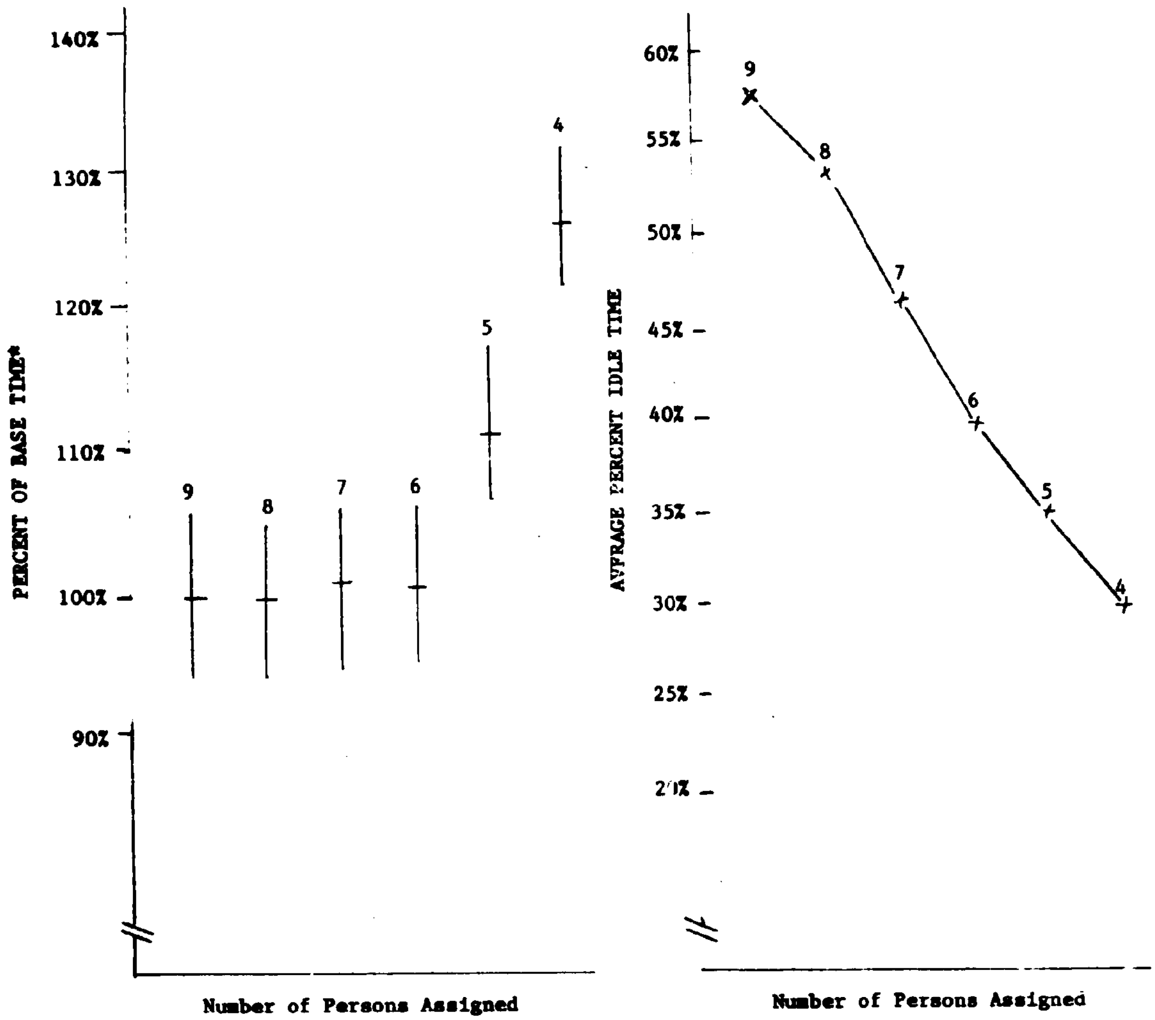


Figure 7. Time required to march-order an M109A1 howitzer section and crew member idle time for various numbers of assigned persons.

*Expressed as a percent of the median nine-man performance time.

Note again that reducing the number of persons assigned to the emplacement tasks from ten to six (five persons and the gun guide) has only a small effect because the improved efficiency of assigned crew members generally compensates for the lesser number of persons. Thus, the six person unit (five persons and a gun guide) is only 5% slower than a ten person unit. As the unit size is reduced to five (four persons and the gun guide) the time penalty increase to 11%, however.

March-Ordering

The TM sequence for march-ordering a howitzer section involves nine men since the gun guide is elsewhere establishing a new location. Here again the reduction in crew members assigned to the tasks makes very little difference until a four person assignment sequence is reached. A five person unit accrues only a 14.7% time penalty but the penalty increases to 28.6% when only four persons perform the basic march-order tasks. The data generated by the model are shown in Figure 7.

CREW STRUCTURE PROBLEM

It appears from the data in Figures 5, 6, and 7 and Table 3 that the number of persons assigned to perform the fighting tasks cannot be reduced enough to provide a support task duty pool large enough to permit all the support tasks, as presently defined, to be accomplished. It also appears that a reduced fighting task unit assignment is desirable since the TM arrangement falls short of providing the needed support personnel. The TM crew assignment arrangement has two other problems. First, peacetime crews generally do not have ten men so the Section Chief rarely gets a chance to use a ten man crew. Second, and much more important, even if it were possible to provide ten man crews

at all times in-garrison the anticipated battle situation would still impose an operating condition which required extensive support task performance and thus vitiates the value of training the fighting tasks with the larger crew using the "TM standard" method. Data from the model indicate it may be possible to create a standard crew utilization approach that can be practiced in peacetime and used in battle.

Three goals necessary for an adequate assignment structure for fighting tasks have already been noted. Two other goals are also needed. These additional goals deal with the need to practice wars in-garrison but to fight them in what are, when the enemy has his way, worst case conditions. To meet these constraints the crew structure adopted for howitzer crew usage needs also:

1. To be effectively applied and practiced in a peacetime mileau.
2. To transfer to battle conditions with a minimal burden on the crew members.

POTENTIAL FOR SUCCESSFUL CREW RESTRUCTURING

The rationale for restructuring crew assignments for fighting tasks is best illustrated by considering the emplacement data shown in Table 4 and Figure 8. These data were obtained when the Crew Performance Model was run to simulate a ten person crew, performing at the skill level of the crews used to collect our base rate data, and performing the tasks as described in the Technical Manual. Two hundred iterations were run. The data represents a crew setting-up and boresighting in a position where the site-to-crest measurement times can include the longer task times required in difficult terrain.

Section A of Table 4 shows emplacement performance data. The median time, the 50th percentile, is marked with a dash. Section B

Table 4

ARI Crew Performance Model Outputs Based on 200 Model Iterations of a Ten Member Crew Emplacing and Boresighting an M109A1 Howitzer Section

CREW SIZE/TASK 10 Member Crew / Emplacement

	Percentile	Seconds	Min:Sec
A.	Max	820	13:40
	90	747	12:27
	80	712	11:52
	70	688	11:28
	60	669	11:09
	50	655	10:55
	40	648	10:48
	30	635	10:35
	20	623	10:23
	10	603	10:03
	Min	533	8:53

	Crew Members		% Waiting	% Working
B.	1 Chief of Section	(CS)	68.6	31.4
	2 Gunner	(G)	36.8	63.2
	3 Assistant Gunner	(AG)	64.8	35.2
	4 Cannoneer #1	(#1)	84.7	15.3
	5 Cannoneer #2	(#2)	89.8	10.2
	6 Cannoneer #3	(#3)	97.8	2.2
	7 Cannoneer #4	(#4)	78.0	22.0
	8 Cannoneer #5	(#5)	61.1	38.9
	9 Howitzer Driver	(HD)	92.9	7.1
	10 Section Driver	(SD)	95.3	4.7
	Average		76.98	23.02

C. 10:55 (Ave. Min) X 10 (No. Men) = 109:10 (Man Minutes Available)

23.02 (Ave. % Working) of 109:10 (Man Minutes Available) = 25:08 (Time Used)

shows another model output, the percentage of time each person was involuntarily idle while waiting for some other person's task to be completed. The "percent working" column in Section B is the working time during the set-up cycle; it is equal to the idle or waiting time subtracted from 100. The calculations shown in Section C of Table 4 and in Table 5 demonstrate the inefficiency of the illustrated crew task structure during emplacement task assignments.

Table 5

Workload and Idle Time for Selected Crew Members of an M109A1 Howitzer Section During Set-Up

Median Time		655 Seconds (10:55)
Total Time Available	(10 X 655)	6550 Seconds (109:10)
Average Workload		23.02%
Total Man-Minutes Work Done	(6550 X .2302)	1547 Seconds (25:08)
Gunner's Workload		63.2%
Gunner's Work Performed	(655 X .632)	414 Seconds (6:54)
Remaining Work	(1547 - 414)	1133 Seconds (18:53)
Manpower Required if All Crew Members Worked as Long as the Gunner	(1133 ÷ 414 = 2.7)	3 + Gunner
Workload if Four Persons and the Gunner Were Available	(1133 ÷ 4 ÷ 655)	43.3%

In the median case, shown in Table 5, the ten man crew took 10 minutes and 55 seconds (655 seconds) to emplace the weapon. Since there were ten persons on the crew, all working on the emplacement, there were a total of 109 minutes and 10 seconds (10:55 X 10) of work time available from the crew. During the median emplacement, however, the average work time for the ten crew members was only 23.02%. Thus, the tasks actually

being performed required only 25 minutes and 47 seconds to complete (109:10 X .2303). Of these tasks the Gunner, who was working the most (63.2% of the cycle), did 6 minutes and 54 seconds of the work performed. Thus, the Gunner performs over 25% of the total work required and only 18 minutes and 53 seconds are needed to perform all the remaining tasks. With a ten person crew this amounts to an average of 2 minutes and 6 seconds of work performed in a period of 10 minutes and 55 seconds by the other nine crew members.

It seems quite obvious that some rearrangement of tasks across a lesser number of crew members is possible. If the remaining tasks can be scheduled among the other crew members so that a lesser number of persons all worked about as long as the Gunner, only three additional crew members would be needed (18.53 ÷ 6.54) for the emplacement tasks. If four additional crew members were available the emplacement tasks might be scheduled among them with each of the four working only 43.3% of the set-up cycle.

Table 6 shows the result of restructuring the task assignments among members of a six member crew. Here again 200 iterations of the Crew Performance Model were run. Note that the man-minutes required to emplace increased slightly from 25:08 for a ten man crew to 26:13. The increase in required working minutes occurred because, with a smaller crew, the crew members must move about more and these movements are considered required tasks; hence, it is part of the crew member's workloads. Note also, however, that the median time required to complete the set-up increased only 33 seconds, from 655 seconds (10:55) to 688 (11:28). This is a total cycle increase of only 5%.

Table 6

ARI Crew Performance Model Outputs Based on 200 Model Iterations of a Six Member Crew Emplacing and Boresighting an M109A1 Howitzer Section

CREW SIZE/TASK 6 Member Crew / Emplacement

	Percentile	Seconds	Min:Sec
A.	Max	834	13:54
	90	763	12:43
	80	738	12:18
	70	717	11:57
	60	705	11:45
	50	688	11:28
	40	673	11:13
	30	658	10:58
	20	635	10:35
	10	620	10:20
	Min	574	9:34

	Crew Members		% Waiting	% Working
b.	1 Chief of Section	(CS)	67.0	33.0
	2 Gunner	(G)	38.1	61.9
	3 Assistant Gunner	(AG)	61.3	38.7
	4 Cannoneer #1	(#1)	78.5	21.5
	5 Cannoneer #2	(#2)	59.9	40.1
	6 Cannoneer #3	(#3)	66.8	33.2
	7 Cannoneer #4	(#4)		
	8 Cannoneer #5	(#5)		
	9 Howitzer Driver	(HD)		
	10 Section Driver	(SD)		
	Average		61.7	38.1

c.	11:28	X	6	=	68:48
	(Ave. Min)	X	(No. Men)	=	(Man Minutes Available)
	38.1	of	68.48	=	26:13
	(Ave. % Working)	of	(Man Minutes Available)	=	(Time Used)

Figure 9 shows the data from the six member crew (5 persons and a gun guide) superimposed upon the relevant data from the ten person crew depicted in Figure 8. The six persons were busier than with a ten person crew structure but all still worked less than the gunner on the ten man crew. The set-up penalty of 5% is the cost of obtaining four persons to perform other work while the gun is being set-up. For example, if these four persons were assigned the camouflage support tasks the gun would be partially camouflaged by the time it was up and ready. Thus, in practice, if camouflage was required, the total time for a six-person crew as outlined here to complete the entire set-up and camouflage cycle would be less than that required by the ten man crew. This conclusion is based upon the assumption that, if needed, the six men getting up the weapon would move to camouflage tasks when the gun is reported up-and-ready. If fire was required immediately the four support crew members and the Gun Guide would finish camouflaging between fire missions.

POSSIBLE TM SOLUTION ALTERNATIVE

It appears from data obtained from the crew model that the TM solution can be significantly modified and thereby provide a better base for fighting a howitzer section. There are many ways in which the existing structure can be changed to better meet the need to provide a larger manpower pool to perform the support functions. One which we have considered, the split crew alternative already mentioned, is to divide the ten person crew into two identical, five-person units (5/5) and to develop a crew utilization approach that alternates the units between the fighting and support tasks.

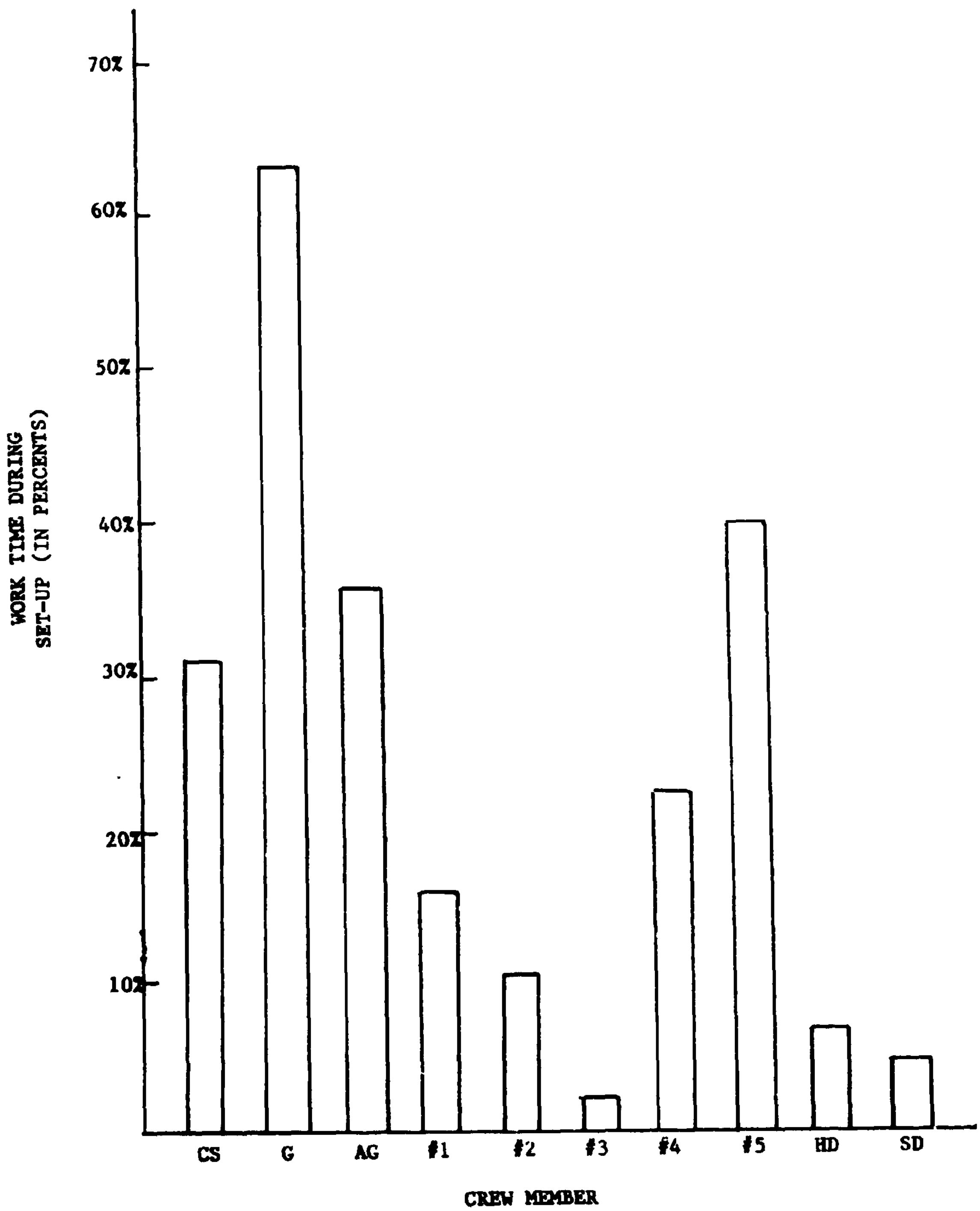


Figure 8. Graphic portrayal of the percent of time worked for a 10 person crew emplacing an M109A1 Howitzer Section as shown in the Technical Manual.

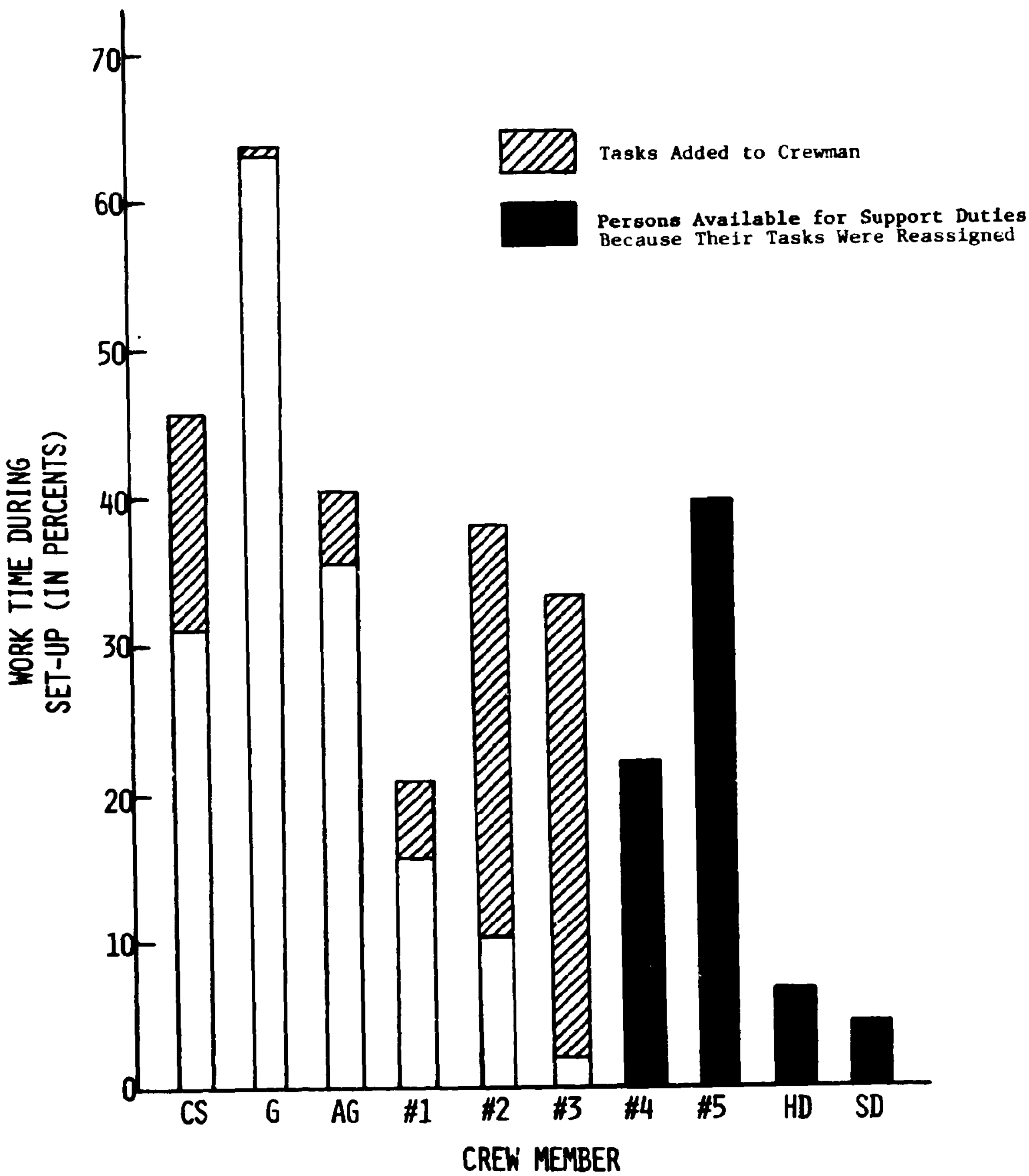


Figure 9. Graphic comparison with Figure 8 data of the percentage of time worked for six persons (5 + Gun Guide) emplacing an M109A1 howitzer section.

A 5/5 crew split is shown in Table 7 where it is compared to the crew as it is designated in the Technical Manual. The TM crew structure consists of ten positions and one person is assigned to each position. The 5/5 crew structure shown postulates two units, designated Red Unit and Gold Unit for convenience in discussion, which are identical except that one unit contains the Chief of Section whereas the other unit is supervised by a Unit Chief.

Table 7

Crew Titles for the TM Crew Structure and for a Two-Equal-Units Crew Division

TM STRUCTURE

Chief of Section	(CS)
Gunner	(G)
Assistant Gunner	(AG)
Cannoneer #1	(#1)
Cannoneer #2	(#2)
Cannoneer #3	(#3)
Cannoneer #4	(#4)
Cannoneer #5	(#5)
Howitzer Driver	(HD)
Section Driver	(SD)

SPLIT CREW STRUCTURE*

Red Unit		Gold Unit	
Chief of Section/Communicator	(CS/C)	Unit Chief/Communicator	(UC/C)
Gunner	(G)	Gunner	(G)
Cannoneer #1	(#1)	Cannoneer #1	(#1)
Howitzer Driver	(HD)	Howitzer Driver	(HD)
Section Driver	(SD)	Section Driver	(SD)

*The revised titles do not represent new crew members. They only represent a redesignation of titles to illustrate the fact that the two units are essentially identical.

In an actual long term continuous battle the split crew operation philosophy would have the Red Unit and Gold Unit alternating between the

fighting tasks and the support tasks. Thus, there would be five persons performing the fighting tasks and five persons available for assignment to support tasks. Appendix A shows task lists for a five person unit emplacing, firing and march-ordering the section. Note that emplacing has six persons available since the gun guide role is considered a support unit function.

Other split crew structures are possible, e.g., six on-gun/four in-support, etc. However, these types of splits are more like the present system where eight persons assigned to the gun during firing is only a nominal condition and the Chief of Section varies the firing unit/support unit distribution as he chooses. It is doubtful that any of the variations of asymmetrical ten person crew divisions are as advantageous, overall, as the symmetrical 5/5 split.

COMPARISON OF THE 5/5 AND TM CREW STRUCTURES

A symmetrical division of a ten-man crew into two equivalent five-man units appears to be a crew structure which can meet the five goals previously stated. There are other advantages as well. Consider how each of the five previously stated goals, reproduced in Table 8, would be met.

Ability to emplace, fire, march-order and transfer a howitzer section

Figures 5, 6, and 7 show the results obtained when the Crew Performance Model was used to determine how well the crews we timed would have performed if they had demonstrated the same skill levels in other crew size and task assigment structures. Selected data from these figures are displayed in Table 9.

Table 8

Five Goals for Developing A Crew Assignment Logic for an M109A1 Howitzer Crew Structure

1. Be able to emplace, fire, march-order and transfer the section in an acceptable time or at an acceptable rate.

2. Permit enough people to be assigned to the support functions that lack of support does not reduce the section's fighting abilities to inadequate levels.

3. Have a reasonable capability to continue to respond, albeit in a degraded mode, when personnel are lost.

4. Be effectively applied and practiced in a peacetime mileau.

5. Transfer to battle conditions with a minimal burden on the crew members.

Table 9

Summary of Data Obtained from the Model Comparing Times to Complete a Fighting Task Sequence and Time Available for Support Duties for the TM Defined Crew Structure and a Possible Five-man Fighting Task Assignment Method

Men Available for Fighting Functions			Men Available for Support Functions		5/5 Time Penalty
	TM Solution	5/5 Solution	TM	5/5	
Emplace	9 + GG	5 + GG	0	4	5.0%
Fire	8	5	2	5	8.6%
March-order	9 + GG	5 + GG	0	4	14.7%
In-transit*	9 + GG	9 + GG	1*	1*	0.0%

*The Gun Guide is not normally in-transit with the crew.

Emplacement. In examining the data displayed in Table 9 the reader should note that the Gun Guide role is considered a part of the support functions and the time spent doing advance party duties and helping to emplace the section are tabulated in Table 3 as replenishment type support tasks. Thus, when a gun is emplaced according to the sequences defined in the already referenced TM the entire crew including the Gun Guide (10 persons) are involved. In the 5/5 solution five persons and the Gun Guide (6 persons) are involved. The median set-up time is 5% longer for the 5/5 structured crew. This is a rather minor time penalty but, in a real sense, even this small penalty does not constitute a liability. The reader should note that with the 5/5 structure four persons are available during the emplacement process to perform support functions. In a hostile environment these four persons would most logically be assigned to set up camouflage or emplace screens. Therefore, when the gun was reported up and ready in the 5/5 case some of the support work would have been completed whereas in the TM case it would all remain to be done. Thus, the time required to have the gun both up and ready and protected would probably be less in the 5/5 case.

Firing. The time decrements which accrue when the number of men assigned to the firing tasks is reduced to five are larger in terms of percentages than in the emplacement sequence. The median time to prepare and fire a first round increased by 8.6%. Here again, however, there are compensations. The most important is that the five man unit concept frees five rather than two persons to perform support functions.

A more subtle compensation is that with only five men involved in the firing cycle there is no excess of crew members so there is a real

pressure to improve crew effectiveness by removing problems rather than merely working around them by applying another pair of hands. For example, in our data collection process ammunition was prepared in the section vehicle. The increase in time to fire a round was the result of the fact that with only five men the projectile/fuze preparation and the powder charge preparation were essentially sequential operations rather than parallel operations as with the larger crew. Equipment changes such as installation of a tube to slide the prepared projectile down, so that it did not have to be carried, would free the second man on section vehicle so that he could prepare the powder charge. This would remove the time penalty by restoring parallel preparation of the projectile and the powder.

Measurable delays also occurred because it took time to crawl over the pallets to get shells from the center or rear of the vehicle and to cut the straps when a pallet was opened. Cutting straps averaged 41 seconds per pallet of eight shells so an average of about five seconds per round fired was the result of the poor equipment furnished to cut straps. Clearly if a strap cutter were placed in the tool kit on the section vehicle the time required to open a new pallet would be reduced considerably—probably to under five seconds—with a consequent reduction of median one round firing time by about four seconds.

Another improvement which would reduce the time required to get a round out involves creating a work station at the rear of the section vehicle. If a round from each pallet could be stored at the rear of the section vehicle the time required to procure rounds from the far end or center of the vehicle would not be part of the round preparation cycle

since a replacement round would be obtained from the work station as the initial round was being fired. It seems clear, therefore, that a chute, a strap cutter and a rack to store shells from each pallet at the rear of the vehicle all would work to decrease the time required to get a first round prepared and fired.

The model can be used to evaluate changes such as these so it was run using appropriate tasks and estimated task times. With these changes the median completion time for the 5/5 firing sequence is faster than the present eight man approach.

March-order. The march-order sequence defined for a five man unit also shows a time penalty. Using only five persons to march-order a howitzer section adds 14.7% to the nine man median completion time. The reason for the time decrement is again a disruption of the parallel flow of events.

With nine persons loading, the march-order moves faster but the decrement is more illusory than real. In an actual battle situation a hasty departure would surely begin with some persons assigned to perimeter defense or other support functions. This being the case the supposition that nine men are immediately available to begin the march-order tasks is not true. The reference median for march-order, the 100% point, was based on the assumption that nine men were immediately available so that the march-order started for all persons immediately and progressed quite rapidly. The 14.7% apparent decrement would have been less if the base case, the TM solution, had not begun with eight men at the gun and one nearby (the Gun Guide having already departed). Actually, given the number and diversity of the support tasks which must

be performed, the 5/5 concept, with an independent, self-contained support unit, may well be faster. In any event the TM crew structure does not define a support unit involving four men scattered about the battery area--and the countryside. It may be, therefore, that a planned support personnel march-order sequence would prevent section personnel from being left or misplaced and maintain the present march-order speed.

It seems that a 5/5 division provides no significant disadvantage in the emplacement and march-order sequences. Furthermore, the decrement which accrues in the first round out situation can be overcome with minimal improvements in the mechanical aids available to a howitzer crew.

In-transit. The in-transit situation would be essentially unaffected by the change to a 5/5 crew structure. In the 5/5 system the unit assigned to the fighting tasks would provide the two drivers required, two air guards and an NCO in-charge. The support unit would provide a gun guide who would probably be off with the advance party. The other four support unit members would do those minor personal support duties which are possible while being transported or else be idle. This is essentially the work/idle situation that presently exists during the in-transit portion of a move.

Permit enough people to be assigned to the support functions that lack of support does not reduce the section's fighting abilities to inadequate levels

Table 3 listed support tasks required to keep a howitzer section functioning in battle conditions. Some of the tasks are required to replenish resources expended as the battle progresses. Other tasks are

intended to reduce the possibility that the section or battery will be exposed to adverse enemy activity that would destroy its resources.

The data in Table 3 are based on the assumption that the section moves often enough and far enough that it is in-transit four hours each 24 hour period. Some of the time estimates, notably guard duty time and involuntary down time, would change if the unit stayed in position over more of the 24 hour period. Other support time estimates might move up or down if better, or different, ways were used to make the estimates. Despite this it seems reasonable to conclude that more than five crew members are required to perform all the possible support functions. It also appears that the support requirements are likely to increase, either in the hours they require or their importance, as the intensity of the battle increases. Thus, for example, as rounds fired and number of positions occupied increases, with enemy surges, the amount of time needed to replenish ammunition and the importance of a perimeter defense/early warning line both increase.

Since no support task becomes easier as the firing rate increases it may be necessary to provide the man-hours needed to accomplish the support tasks required when the howitzer is operating at or near the maximal fighting requirement. Thus, it is probably reasonable to assume that five persons assigned to the support functions are not really enough. However, five persons may represent the minimal number that enables a reasonable authority to set priorities and select among the competing support tasks for those with the most urgency.

Clearly a 5/5 split crew strategy provides the best available strategy for coping with the great demand. However, it is also the case that five persons provide only 120 man-hours per day (100 if four hours

are used moving) and that the support requirements do exceed this amount. It also appears that some battle situations could expand the replenishment and/or involuntary down time categories sufficiently that no time remains for performing the risk reducing tasks. In summary, it seems that the 5/5 crew structure comes as close as possible to meeting the support requirements, but as we will see later there could be a realistic case made for an eleventh man on a howitzer crew.

Have a reasonable ability to continue to respond, in a degraded mode, when personnel are lost

In order to evaluate the reasonableness or acceptability of a degraded response mode it is necessary to have a clear definition of the condition from which the degradation occurs. In the TM case where 10, 8 and 9 persons are specified for set-up, firing and march-order task sequences, the data displayed in Figures 5, 6, and 7 imply there would be no degradation if one, two or even three persons are lost. This is the case because there is so much idle time per crew member that reduction to a six person unit can apparently be absorbed with no time penalty.

We have already seen, however, that the support requirements place a considerable burden on the manpower available in a howitzer section. Also, even when five persons, half of the available manpower, are assigned to support functions the support duties are not fully staffed. The problem in defining a degraded mode operation is therefore really one of deciding how many support tasks can be dropped before the only available solution to compensating for further losses is to reduce fighting effectiveness.

It seems also that the 5/5 solution is well prepared to provide a point of departure for degraded mode evaluations. Battery losses of up to 10%, one man per section, can be absorbed by reducing the support task units from five to four persons. If further battery losses occur deletions from the persons assigned to fighting task units could be made until sections are operating in a 4/4 condition.

In a 4/4 condition, sections and the battery to which they are attached, would be operating more slowly and at a greater risk of suffering either adverse actions or having inadequate replenishment capability. In either event the battery with 20% casualties would most certainly be in one of two conditions. In one case a battery with 20% personnel losses would most probably have lost materiel so personnel from inoperative sections would be available to other sections as replacements to move back to a 5/5 crew situation but with fewer sections. The other condition, 20% personnel losses without materiel losses, would surely be seen as approaching the point where battle casualties are at an intolerable level and a reduced individual section response capability would be expected and seen as an unavoidable constraint on the Field Artillery's ability to respond.

Another advantage of the 5/5 crew assigment structure which affects the section's ability to respond adequately with reduced people is its symmetry which creates two persons for each job. In the assignment approach defined in the TM there is one Gunner, one Assistant Gunner, etc. Presumably, the Section Chief spends some time training persons for other jobs, but training is difficult given the high turbulence and non-standard crew structures that Section Chiefs must create to respond

to manpower shortfalls. With the 5/5 model a full crew of ten persons has two persons trained for each position. Thus, there are two Gunners, two Section Vehicle Drivers, etc. Furthermore, as we will see later, personnel turbulence has less impact on a 5/5 division so Section Chiefs can more easily rotate personnel within units so that individual crew members can learn to function in other unit roles.

Be effectively applied and practiced in a peacetime mileau

The contrast between the TM assignment method and the 5/5 concept is well illustrated by comparing the effects of the various peacetime manning problems on the potential effectiveness of crews subjected to them. Two basic manning problems exist in the present Field Artillery cannon batteries. One is that many batteries do not have a full complement. The other is that there are intolerably high levels of turbulence in section crews.

Both of these problems, short manning and turbulence, have far more significant effects on the TM structure than they would have on a battery structured to support the 5/5 structure. The most obvious problem associated with using the 10/8/9 man emplace/fire/march-order structure is that a section must have ten crew members to use it. Since batteries often have between 50 and 60 persons rather then the 80 required to give each section a ten man crew there is usually no opportunity to create or to practice ten man crews. This being the case Section Chiefs must improvise and create their own crew task assignment structures.

This non-standardized approach in turn is particularly vulnerable to the effects of turbulence. The absence or shifting of personnel from

a crew because of internally created turbulence or the replacement of existing crew members by new persons creates situations that are hard to overcome. Either the section must operate differently with a smaller crew or attention must be given to retraining the new man to operate in his new position or new crew.

The effects of this problem are illustrated in Part A of Figure 10. Figure 10 shows the distribution of 58 crew members among eight howitzer sections in an understrength battery. The circled figures represent crew members absent on a particular day. For purposes of the example a 15% absenteeism rate (9 persons) was assumed and absences were randomly assigned to the eight crews.

The condition depicted in Part A of Figure 10 is probably typical of a howitzer battery unless special pressure has been brought to bear on maintaining a full and present complement. Typically batteries will be undermanned, and leaves, schools, sick calls and assignments to other battery duties will, in an almost random fashion, create vacant positions in the various howitzer crews. When these vacancies occur, two responses are possible: operate with the reduced crew size or fill some crews at the expense of other crews. The first solution simply aggravates the crew size problem. The Section Chief must quickly adapt to a smaller crew and a different crew task assignment structure. The latter solution is really not much better than the first since it generally represents an attempt to shore up a seriously understrength crew by assigning the weaker members of a larger crew to the decimated crew. This in turn aggravates the turbulence problem.

In the case shown in Figure 10 Part A the battery would nominally

A. TM STRUCTURE

SECTION NUMBER

	1	2	3	4	5	6	7	8
CS	X	X	X	X	X	X	X	X
G	X	X	X	X	X	X	X	X
AG	X	X	X	X	X	X	X	X
HD	X	X	X	X	X	X	X	X
SD	X	X	X	X	X	X	X	X
#1	X	X	X	X	X	X	X	X
#2	X	X	X	X	X	X	X	X
#3	X	X						

B. 5/5 STRUCTURE

SECTION NUMBER

		1	2	3	4	5	6	7	8
RED UNIT	CS/C*	X	X	X	X	X	X	X	X
	G	X	X	X	X	X	X	X	X
	#1	X	X	X	X	X	X	X	X
	HD	X	X	X	X	X	X	X	X
	SD	X	X	X	X	X	X	X	X
GOLD UNIT	UC/C	X	X	X					
	G	X	X	X					
	#1	X	X	X					
	HD	X	X	X					
	SD	X	X	X					

X, X, X Unassigned

Figure 10. Crew assignments for TM and 5/5 based crew structures with a representative absenteeism condition illustrated.

*The Chief of Section

Absent Crew Member

have two eight-man crews and six seven-man crews. In the depicted case with nine men absent changes affect all the crews except one. One way to attempt to restore the crews to their nominal size would involve taking the crew members from Section #6, because it has no Section Chief, and distributing them among the other crews. This would leave one section unmanned, restore five of the remaining crews to their original strength, and leave two crews one man short.

Other substitution strategies could be used but they would all impose similar problems on the battery. Because individual crew member duties are not rigidly defined the "new" crew members would be in somewhat unfamiliar situations and would not perform at their previous skill levels without practice. Also, the only way a crew can be restored to its original manning level is by reducing some other crew. This reduction process must either "rob Peter to pay Paul" or simply remove one crew entirely.

Figure 10 Part B shows the basic assignment of the same number of crew members if the 5/5 strategy were in use. In this case three of the sections start with a full ten member complement, five have only a five person crew and three persons are "unassigned". With the same number of absentees as before the 5/5 strategy and its affiliated standardization of crew structure, overcomes the missing manpower problem more satisfactorily. First, of course, the three supernumeraries can be assigned to Red Units. With this done three of five undermanned Red Units are now at full unit strength. Moving the two crew members remaining in the #2 Gold Unit to the remaining two Red crew vacancies fills the remaining Red vacancies. With these temporary transfers made <u>all</u> <u>howitzers</u> are

available with a basic crew. One howitzer has a two unit crew, and four persons--the remaining personnel of the #1 Gold Unit--are available for assignment elsewhere by battery command personnel on an "as-needed" basis. All guns have crews with this assignment method. However, there remains only one section with a ten man crew, whereas the battery nominally had three such crews, and there are four "extras" instead of three. (Note that with the 5/5 structure there can only be one to four persons extra. With a fifth a new unit is formed and assigned to a section, and the extra list drops to zero.)

The advantages of the 5/5 model are evident in this example. Note that in Figure 10 Part B:

1. All howitzer sections have at least a standard size base crew at all times.

2. There should be little crew performance decrement when persons are assigned to other units since, because of better standardization assignment to a different unit changes only associates not tasks.

3. No Section Chief has to change his crew's task assignments since the basic crew size and crew structure has not changed.

4. The five person structure lends itself to practicing realistic field exercises since units can obtain persons for support duties in either of two ways. They can elect to go to the field with full crews but a reduced number of sections or they can take full batteries and alternate half staffed sections between firing and support duties in order to practice both types of duties.

<u>Transfer to battle conditions with minimal burden on the crew members</u>

The 5/5 structure also appears superior in moving from a peacetime to a wartime situation with minimal impact. Standardization, which is

the basis for the 5/5 approach, makes it possible to bring a battery up to full strength by merely adding units. As new units arrive at a battery they simply convert sections from half manned sections to fully manned sections. This saves Section Chiefs from the need to move from a poorly defined crew structure to the ten person TM structure, a structure which may not work as we have already noted.

If the reader refers again to Figure 10 the 5/5 structure's advantage when moving from an understaffed condition to a fully staffed condition becomes quite apparent. Note that in Figure 10 Part A there really is no standardized base structure. Thus, as people arrive to fill the empty slots the turbulence effect is considerable and time is required to train the new people. With the 5/5 concept there is a standard base structure and, hence, there is little turbulence effect, since Section Chiefs simply move from the five man base crew to the full crew condition and simply have two units rather than one.

ARE TEN MEN ENOUGH?

It may have occurred to the reader that even the 5/5 structure, although better adapted to high intensity battles than the ten man structure, may not be able to cope adequately with the worst-case days. Figure 3 showed an estimate of rounds fired versus day of battle for an initial battle in Europe projection. It also showed a potential move rate based on the assumption that a section is likely to be forced into a move situation—to avoid counterfire or to prevent being overrun--on the average of once for every 50 rounds fired. Obviously as rounds fired moves toward the 500 per day rate all the support functions become more critical, e.g., more ammunition is required, more POL is used, men require their sleep more and the need for an early warning

becomes more likely to be factor in preventing the battery from being adversely affected by events in the surrounding area.

It was previously suggested that five persons do not provide enough man-hours to perform all the support tasks. There is also a potential problem in the 5/5 structure because it requires that the Section Chief be a more integral part of the functioning of both the fighting and supporting crew units. The 5/5 approach--which sees the Section Chief as a "working leader"--is probably suitable for low fire rate conditions, because when fire rates are low the Section Chief can put the gun on a four person crew structure (the degraded mode) and perform other duties. If the Section Chief is with the support unit he can assign his support personnel in such a fashion that he is free to attend to other duties should they arise.

Unfortunately, both these options become less viable as the firing and move rates increase. When high fire and move rates are imposed on a crew already short of support personnel the lack of support personnel will cause risk to the battery to rise and replenishment to become more difficult. Under these conditions a case can be made for an 11th man on a full crew and a sixth man on a one-unit crew. This crew size would make it possible to gain all the advantages of the 5/5 structure, maintain a Chief of Section role more like the traditional one, and obtain an additional capability in the support task area. The 5/5/1 or "augmented 5/5" crew structure is depicted in Figure 11. This crew structure would require 88 howitzer crew members in a fully staffed battery and it would be better able to respond to high intensity battle requirements.

		SECTION NUMBER							
		1	2	3	4	5	6	7	8
RED UNITS	AG/C	X	X	X	X	X	X	X	X
	G	X	X	X	X	X	X	X	X
	#1	X	X	X	X	X	X	X	X
	HD	X	X	X	X	X	X	X	X
	SD	X	X	X	X	X	X	X	X
	CS	X	X	X	X	X	X	X	X
GOLD UNITS	AG/C	X	X						
	G	X	X						
	#1	X	X						
	HD	X	X						
	SD	X	X						

Figure 11. Personnel assignments for a 58 man complement assigned to an augmented 5/5 (5/5/1) crew structure.

No change would have to be made in the present actual average manning of howitzer sections to implement an augmented 5/5 structure. Note that the battery depicted in Figure 11 has the same number of men as the battery depicted in Figure 10. However, because of the organizational structure, and the improved standardization that results from both the 5/5 and the 5/5/1 approach, batteries organized in either of these ways have two great advantages over the present TM organization: They adapt to reduced manning levels with less difficulty and they can expand to a full complement with little difficulty.

CONCLUSIONS

An analysis using the Crew Performance Model has shown that it can be used to determine the effects of certain types of crew structure changes on the speed with which the crew accomplishes time sensitive task sequences. It has also been demonstrated that the model can be used in conjunction with standard scheduling techniques to determine the impact of varying crew structures on the ability of a crew to respond to requirements that cannot be directly incorporated into the model.

Data obtained by running the model show that certain M109A1 howitzer crew structure alternatives are very effective and merit consideration as possible alternatives to the structure described in the current Technical Manual. The alternative crew structures appear to provide a section crew that:

1. Can emplace, fire, march-order and transfer a howitzer section in approximately the same time as the present ten man crew structure but requires the use of fewer men.

2. Makes a larger portion of the crew's total man-hours available for scheduling of support functions.

3. Has the ability to continue to respond with timely fire when personnel are lost.

4. Can be installed and used more effectively in a garrison situation than the present crew structure.

5. Will transfer to battle situations with fewer problems than the present crew structure.

The analysis has also shown that the crew model is a suitable base upon which to develop a method to predict the impact of parameters which affect crew performance and the impact of equipment changes on crew performance.

REFERENCES

Coke, J. S., Crumley, L. M., & Schwalm, R. C. Emplacing, firing and march-ordering an M109A1 howitzer: Tasks and task times (Research Report 1312). Alexandria, VA: U. S. Army Research Institute for the Behavioral and Social Sciences, 1981.

Crumley, L. M., & Schwalm, R. C. Analysis of TCATA data from a work sampling of M109A1 howitzer crew duty assignments during a 96 hour field evaluation (FT 382H) (Working Paper FSFU 80-4). Fort Sill, Oklahoma: U. S. Army Research Institute for the Behavioral and Social Sciences, 1980.

Department of the Army. Technical manual operation and maintenance manual (User) for howitzer medium self-propelled: 155mm, M109A1 (2350-00-485-9622) (TM 9-2350-217-10N). Washington, D. C.: Department of the Army, Headquarters, 1978.

Schwalm, R. C., Crumley, L. M., Coke, J. S., & Sachs, S. A. A description of the ARI Crew Performance Model (Research Report 1324). Alexandria, VA: U. S. Army Research Institute for the Behavioral and Social Sciences, 1981.

This page intentionally left blank.

APPENDIX

Tasks and Crew Member Task Assignment Lists for Emplace and Boresight, Fire and March-Order Using a Ten Man Crew Divided into Two Five Man Units

Emplace and Boresight Task Assignments

```
@XQT GN.LIST
  1   400  OPENS REAR HULL DOOR WHILE DISMOUNTING
  1  1002  EXITS BACK OF HOWITZER (REAR HULL DOOR IS OPEN)
  1   300  PREPARES LEFT SPADE FOR EMPLACEMENT
  1  1022  MOVES DISTANCE BETWEEN BACK OF HOW & A SIDE CAB WINDOW
  1     2  DIRECTS MD IN BACKING ON TO SPADES
  1  1022  MOVES DISTANCE BETWEEN BACK OF HOW & A SIDE CAB WINDOW
  1     4  CHECKS SPADE STRUTS
  1  1022  MOVES DISTANCE BETWEEN BACK OF HOW & A SIDE CAB WINDOW
  1     6  DIRECTS MD TO SET BRAKES AND TURN OFF VEHICLE [WHILE MOVING]
  1  1024  MOVES DISTANCE BETWEEN BACK & FRONT OF HOWITZER
  1  1046  MOUNTS FRONT OF HOWITZER, MOVES TO RECUPERATOR GUIDE PINS
  1     8  CHECKS FRONT RECUPERATOR GUIDE PINS
  1  1050  DISMOUNTS SIDE OF HOWITZER FROM RECUPERATOR PINS
  1  1042  MOVES DISTANCE BETWEEN FRONT & BACK OF HOWITZER (INSIDE)
  1    10  CHECKS REAR RECUP PINS, REPLEN GAUGE, + RECOIL SYSTEM
  1    12  VERIFIES LAY OF HOWITZER
  1    14  SELECTS ALTERNATIVE AIMING POINT
  1    16  INFORMS G OF ALTERNATIVE AIMING POINT
  1    18  DIRECTS G + AG TO MEASURE SITE TO CREST
  1    20  ESTIMATES DISTANCE TO CREST, REPORTS TO XO + FDC
  1    22  DIRECTS G + AG TO BORESIGHT
  1    24  SUPERVISES BORE SIGHTING
  1    26  VERIFIES BORE SIGHTING
  2   100  OPENS LEFT CAB DOOR
  2   102  MOVES TO DEPRESS LEFT PEDAL LATCH, RETURNS TO STATION
  2   202  MOVES TO DEPRESS RIGHT PEDAL LATCH, RETURNS TO STATION
  2   104  REMOVES COLLIMATOR, PASSES IT OUT, DIRECTS MAN TO LOCATION
  2   106  SETS CAB POWER SWITCH TO ON, SETS TRAVERSE CONTROL SWITCH
  2   108  AS DIRECTED BY MD, G RAISES TUBE
  2   110  DEPRESSES TUBE TO MINIMUM ELEVATION
  2   112  SELECTS AG POSITION FOR POWER ELEVATION CONTROL
  2   114  G RELEASES LATCHES ON BALLISTIC COVER
  2   116  OBTAINS AND INSTALLS PANORAMIC TELESCOPE
  2   118  G + GUN GUIDE DECIDE LOCATIONS FOR AIMING POSTS
  2   120  SETS DEFLECTION TRAVERSES WEAPON TO AIMING POINT
  2   122  TALKS WITH XO, TRAVERSES, ANNOUNCES READY FOR RECHECK [1ST]
  2   124  TALKS WITH XO, TRAVERSES, ANNOUNCES READY FOR RECHECK [2ND]
  2   126  WHEN XO SAYS 0 MILS, G REPORTS GUN LAID, RECORDS DEFLECTION
  2   128  DIRECTS MAN IN ALIGNMENT OF COLLIMATOR, RECORDS DEFLECTION
  2   130  RESETS COUNTER TO 3200 MILS
  2   134  MOVES PANTEL TO ALTERNATIVE AIMING POINT, RECORDS IT
  2   136  WHEN DIRECTED BY CS, G + AG MEASURE SITE TO CREST
  2   138  RETURNS PANTEL TO COLLIMATOR
  2   140  G BORE SIGHTS AND RETURNS PANTEL TO COLLIMATOR
  3  1000  EXITS BACK OF HOWITZER (AFTER REAR DOOR IS OPENED)
  3   402  PREPARES RIGHT SPADE FOR EMPLACEMENT
  3  1041  MOVES DISTANCE BETWEEN BACK OF HOWITZER AND FRONT OF SV
  3   500  DIRECTS SD INTO POSITION
  3  1040  MOVES DISTANCE BETWEEN BACK & FRONT OF SV
  3   502  OPENS REAR DOOR OF SECTION VEHICLE
  3  1020  MOVES DISTANCE BETWEEN BACK OF HOWITZER & BACK OF SV
  3  1010  ENTERS BACK OF HOWITZER, MOVES TO POSITION
  3   200  OPENS RIGHT CAB DOOR
  3   204  ELEVATES TUBE TO LOADING ELEVATION
```

Emplace and Boresight Task Assignments

3	206	WHEN DIRECTED BY CS, G + AG MEASURE SITE TO CREST
3	208	RETURNS TUBE TO LOADING ELEVATION
3	210	DEPRESSES TUBE FOR ATTACHMENT OF M-140 DEVICE
3	212	AG BORE SIGHTS + CHECKS DIRECT FIRE TELESCOPE
3	214	AG RETURNS TUBE TO LOADING ELEVATION
4	800	MD BACKS HOWITZER ONTO SPADES
4	802	MD SETS BRAKES AND TURNS OFF VEHICLE
4	804	MD EXITS HATCH
4	806	DIRECTS G TO RAISE TUBE, DISENGAGES + STOWS TRAVEL LOCK
4	808	OPENS + UNLOCKS DIRECT FIRE TELESCOPE COVER
4	810	MOVES TO BALLISTIC COVER, SIGNALS G
4	812	LIFTS + LOCKS BALLISTIC COVER
4	814	MD STOWS INSTRUMENT PANEL
4	816	MD SECURES HATCH
4	1052	DISMOUNTS NEAR SIDE OF HOWITZER OVER TRACKS
4	1042	MOVES DISTANCE BETWEEN FRONT & BACK OF HOWITZER (INSIDE)
4	302	CHECKS FUNCTION OF FIRING MECHANISMS
4	304	INSPECTS, CLEANS, OPERATES BREECH BLOCK + POWER RAMMER
4	306	PROCURES + SECURES WATER BUCKET AND SPONGE
4	308	PROCURES PRIMERS, PLACES THEM IN A CONVENIENT + SAFE LOCATION
5	900	SD MOVES SV INTO POSITION
5	902	SD TURNS SV OFF, LOCKS BRAKES
5	1038	MOVES DISTANCE BETWEEN FRONT OF SV & FRONT OF TUBE
5	702	REMOVES MUZZLE COVER
5	1026	MOVES DISTANCE BETWEEN BACK OF HOWITZER & FRONT OF TUBE
5	704	STORES MUZZLE COVER
5	600	OBTAINS + ASSEMBLES AIMING POSTS
5	708	G + GUN GUIDE(OR ANOTHER) DECIDE LOCATIONS FOR AIMING POSTS
5	710	EMPLACES AND ADJUSTS AIMING POSTS
5	712	AIMING POST SETTER RETURNS TO WEAPON
5	1010	ENTERS BACK OF HOWITZER, MOVES TO POSITION
5	404	GATHERS FUZE SETTERS IN HOWITZER
5	1000	EXITS BACK OF HOWITZER (AFTER REAR DOOR IS OPENED)
5	1020	MOVES DISTANCE BETWEEN BACK OF HOWITZER & BACK OF SV
5	1012	ENTERS BACK OF SV
5	406	ARRANGES FUZE SETTERS AND WRENCHES IN SV
5	408	OPENS AND ARRANGES FUZE BOXES
6	1024	MOVES DISTANCE BETWEEN BACK & FRONT OF HOWITZER
6	700	INSTALLS BATTERY COMMUNICATION SYSTEM
6	1022	MOVES DISTANCE BETWEEN BACK OF HOW & A SIDE CAB WINDOW
6	602	RECEIVES COLLIMATOR
6	604	MOVES TO SET COLLIMATOR
6	606	REMOVES COVER, FOCUSES COLLIMATOR ON G'S SCOPE
6	608	ALIGNS COLLIMATOR
6	610	RETURNS TO SECTION VEHICLE FROM COLLIMATOR
6	504	HELPS MAN OPEN + ARRANGE FUZE BOXES
6	1020	MOVES DISTANCE BETWEEN BACK OF HOWITZER & BACK OF SV
6	1010	ENTERS BACK OF HOWITZER MOVES TO POSITION
6	714	OBTAINS M-140 DEVICE
6	1000	EXITS BACK OF HOWITZER (AFTER REAR DOOR IS OPENED)
6	1026	MOVES DISTANCE BETWEEN BACK OF HOWITZER & FRONT OF TUBE
6	716	ATTACHES M-140 DEVICE TO TUBE
6	718	REMOVES M-140 DEVICE
6	1026	MOVES DISTANCE BETWEEN BACK OF HOWITZER & FRONT OF TUBE
6	1010	ENTERS BACK OF HOWITZER, MOVES TO POSITION
6	720	STORES M-140 DEVICE

Fire Mission Task Assignments

```
@XQT MODEL*GN.LIST
  1     2  RECEIVES + ANNOUNCES FIRE MISSION
  1     4  ANNOUNCES PROJECTILE
  1     6  ANNOUNCES CHARGE
  1     8  ANNOUNCES FUZE
  1    10  IF FUZE IS TIME, STATES TIME
  1    12  ANNOUNCES DEFLECTION
  1    14  ANNOUNCES QUADRANT
  1  1043  MOVES SHORT DISTANCE
  1    20  VERIFIES ADJUSTMENT OF FIRE CONTROL INSTRUMENTS
  1  1043  MOVES SHORT DISTANCE
  1    24  INSURES WEAPON IS SAFE TO FIRE
  1    26  REPORTS PIECE READY, RECEIVES + GIVES COMMAND TO FIRE
  2   100  SETS DEFLECTION
  2   102  TRAVERSES TUBE
  2   104  AFTER AG CALLS SET, ENSURES BUBBLES ARE LEVEL + CALLS READY
  3   200  SETS QUADRANT
  3   202  ELEVATES TUBE TO FIRING POSITION, CALLS SET
  4   300  RECEIVES PROJECTILE + MOVES TO LOAD POSITION
  4   302  LOADS PROJECTILE + SETS RAMMER
  4  1043  MOVES SHORT DISTANCE
  4   304  RECEIVES CHARGE AND MOVES TO LOAD POSITION
  4   306  LOADS PROPELLANT CHARGE + SETS FIRING MECHANISM
  4  1043  MOVES SHORT DISTANCE
  4   308  INSERTS PRIMER + CLOSES BREECH BLOCK
  4  1043  MOVES SHORT DISTANCE
  4   310  ATTACHES LANYARD TO FIRING MECHANISM
  4   312  FIRES WEAPON AND CALLS QUADRANT + ROUND, IF NECESSARY
  4   314  SWABS AND CLEANS POWDER CHAMBER
  4   316  INSPECTS BORE + ANNOUNCES BORE CLEAR
  4   318  UNHOOKS LANYARD AND SETS IT DOWN
  5   400  SELECTS + PREPARES PROJECTILE
  5   402  SELECTS PROPER FUZE
  5   404  AFFIXES + SETS FUZE
  5  1008  EXITS BACK OF SV
  5   502  CARRIES PROJECTILE TO HOWITZER
  5   504  RETURNS TO REAR OF SECTION VEHICLE [PROJO]
  5   600  SELECTS + UNPACKS CHARGE
  5   602  CUTS PROPER CHARGE
  5   800  RECEIVES CHARGE, MOVES TO HOWITZER, PASSES CHARGE IN
  5   802  RETURNS TO REAR OF SECTION VEHICLE [CHARGE]
  5   806  CARRIES EXCESS POWDER TO POWDER DUMP
  5   808  RETURNS FROM POWDER DUMP TO SECTION VEHICLE
```

March-Order Task Assignments

```
@XQT GN.LIST
 1    2  CEIVES MARCH ORDER. GIVES COMMAND TO MARCH ORDER
 1  500  OBTAINS MUZZLE COVER
 1 1002  EXITS BACK OF HOWITZER (REAR HULL DOOR IS OPEN)
 1 1026  MOVES DISTANCE BETWEEN BACK OF HOWITZER & FRONT OF TUBE
 1  502  INSTALLS MUZZLE COVER
 1  600  MOVES TO GET AIMING POSTS, STORES THEM IN HOWITZER
 1 1022  MOVES DISTANCE BETWEEN BACK OF HOW & A SIDE CAB WINDOW
 1    4  DIRECTS MD TO START HOWITZER AND MOVE BACKWARDS
 1    6  DIRECTS MD TO PULL FORWARD AND STOP
 1    8  DIRECTS SD TO START SECTION VEHICLE
 1 1022  MOVES DISTANCE BETWEEN BACK OF HOW & A SIDE CAB WINDOW
 1  308  LIFTS + LOCKS LEFT SPADE
 1   10  CHECKS SPADES FOR SECURITY
 1   12  DIRECTS CREW TO MOUNT UP, MAKES CHECKS, SIGNALS XO
 1  604  PUSHES LEFT CAB DOOR SHUT FOR GUNNER
 1 1048  MOUNTS FRONT OF HOWITZER, MOVES TO COMMAND CUPOLA
 1   14  UNLOCKS CUPOLA + ENTERS
 2  104  RETURNS ELEVATION CONTROL TO GUNNER
 2  200  LOWERS TUBE TO MINIMUM ELEVATION
 2  100  PREPARES TELESCOPE MOUNT FOR TRAVEL
 2  102  STORES PANORAMIC TELESCOPE FOR TRAVEL
 2  106  ELEVATES TUBE TO PREPARE FOR TRAVEL
 2  108  TRAVERSES GUN AS DIRECTED BY MD
 2  110  LOWERS TUBE AS DIRECTED BY MD
 2  112  CAB POWER TO OFF.LOCKS CAB TRAVERSE,SPADES CAN BE STORED
 2  114  DEPRESSES LEFT PEDAL AND ADVISES MD SPADE IS UNLOCKED
 2 1043  MOVES SHORT DISTANCE
 2  206  DEPRESSES RIGHT PEDAL AND ADVISES MD SPADE IS UNLOCKED
 2  116  RECEIVES COLLIMATOR AND STORES IT
 2  118  CLOSES LEFT CAB DOOR
 2 1043  MOVES SHORT DISTANCE
 2  204  CLOSES RIGHT CAB DOOR
 2  310  ENTERS HOWITZER, SECURES REAR DOOR IN POSITION
 2 1018  ASSUMES TRAVEL POSITION IN HOWITZER
 3  202  PREPARES ELEVATION QUADRANT FOR TRAVEL
 3 1002  EXITS BACK OF HOWITZER (REAR HULL DOOR IS OPEN)
 3 1022  MOVES DISTANCE BETWEEN BACK OF HOW & A SIDE CAB WINDOW
 3  602  DISCONNECTS COMMO LINES FROM TERMINALS, STORES PHONE
 3  504  MOVES TO COLLIMATOR, PUTS COVER ON IT, TAKES IT TO G
 3  410  LIFTS AND LOCKS RIGHT SPADE
 3 1041  MOVES DISTANCE BETWEEN BACK OF HOWITZER AND FRONT OF SV
 3 1014  ENTERS FRONT OF SV, MANS 50 CAL
 4  300  CLOSES BREECH BLOCK
 4  302  SECURES THE POWER RAMMER
 4  304  SECURES SPONGE, BURLAP, + CLEANING MATERIALS
 4  306  PLACES UNUSED PRIMERS IN TRAVEL COMPARTMENTS
 4 1002  EXITS BACK OF HOWITZER (REAR HULL DOOR IS OPEN)
 4 1024  MOVES DISTANCE BETWEEN BACK & FRONT OF HOWITZER
 4 1044  MOUNTS FRONT OF HOWITZER, MOVES TO TRAVELING LOCK
 4  800  LIFTS GUN TRAVEL LOCK
 4  802  MD DIRECTS G TO TRAVERSE GUN
 4  804  MD GIVES INSTRUCTIONS FOR GUN TO BE LOWERED
 4  806  LOCKS TUBE IN TRAVEL LOCK POSITION
 4  808  MOVES TO BALLISTICS SHIELD, LOWERS + LOCKS IT
```

4	810	MOVES TO AND CLOSES DIRECT FIRE TELESCOPE
4	812	MD OPENS DRIVER'S HATCH, ENTERS, POSITIONS HIMSELF
4	814	MD INSTALLS INSTRUMENT PANEL OUTSIDE OF HATCH
4	816	AS DIRECTED BY CS, STARTS HOWITZER + MOVES BACKWARD
4	818	MD ADVISES CS THAT SPADES ARE UNLOCKED
4	820	AS DIRECTED BY CS, MD DRIVES FORWARD + STOPS
5	1043	MOVES SHORT DISTANCE
5	1012	ENTERS BACK OF SV
5	400	GATHERS FUZE SETTERS
5	1008	EXITS BACK OF SV
5	1020	MOVES DISTANCE BETWEEN BACK OF HOWITZER & BACK OF SV
5	1010	ENTERS BACK OF HOWITZER, MOVES TO POSITION
5	402	STOWS FUZE SETTERS IN HOWITZER
5	1002	EXITS BACK OF HOWITZER (REAR HULL DOOR IS OPEN)
5	1020	MOVES DISTANCE BETWEEN BACK OF HOWITZER & BACK OF SV
5	1012	ENTERS BACK OF SV
5	404	STOWS UNUSED FUZES IN CONTAINERS
5	1008	EXITS BACK OF SV
5	1020	MOVES DISTANCE BETWEEN BACK OF HOWITZER & BACK OF SV
5	1010	ENTERS BACK OF HOWITZER, MOVES TO POSITION
5	406	STORES FUZE CONTAINERS IN HOWITZER
5	1002	EXITS BACK OF HOWITZER (REAR HULL DOOR IS OPEN)
5	1022	MOVES DISTANCE BETWEEN BACK OF HOW & A SIDE CAB WINDOW
5	408	PUSHES RIGHT CAB DOOR SHUT FOR AG
5	900	MOVES TO DRIVER STATION OF SECTION VEHICLE
5	902	SD STARTS SECTION VEHICLE + UNLOCKS BRAKES

This page intentionally left blank.